6. Defendant, from and after November 30, 1951, has used and continues to use said mill and equipment coming under said United States Letters Patent and has practiced and continues to practice processes coming within the scope of said patents and has used and sold the products of said mill, equipment and processes, but, nevertheless, has failed and refused and continues to fail and refuse to pay to plaintiff the royalties due pursuant to the terms of said agreement. Plaintiff is without sufficient knowledge and information to enable it to state the exact amount of the royalties due for the period subsequent to November 30, 1951, and, therefore, seeks discovery and an accounting in respect thereof.

WHEREFORE, plaintiff demands:

A. Discovery and an accounting in respect of the additional royalties due plaintiff pursuant to said agreement for the period from April 1, 1949 to November 30, 1951.

B. Judgment in its favor for the additional royalties found to be due plaintiff under said agreement for the period from April 1, 1949 to November 30, 1951, together with interest at the rate of six percent (6%) on any such additional royalties for the period from the date when such additional royalties became due pursuant to the terms of said agreement to the date of the entry of a final judgment herein.

C. Discovery and an accounting in respect of the royalties due plaintiff pursuant to said agreement for the period subsequent to November 30, 1951.

D. Judgment in its favor for the total amount of the royalties due pursuant to the terms of said agree-

ment for the period subsequent to November 30, 1951, together with interest thereon at the rate of six percent (6%) from and after the date when each such royalty payment became due pursuant to the terms of said agreement.

E. Judgment for costs and reasonable attorneys' fees.

F. Such other and further relief as to this Court may seem meet and proper.

THE COLD METAL PRODUCTS COMPANY

By EDWARD J. O'MARA

Edward J. O'Mara
1 Exchange Place
Jersey City, New Jersey

WILLIAM H. WEBB
1220 Farmers Bank Building
Pittsburgh 22, Pennsylvania,

Attorneys for Plaintiff.

O'MARA, SCHUMANN, DAVIS & LYNCH,
WEBB, MACKEY & BURDEN,
Of Counsel.

December 16, 1952.

Defendant's Answer and Counterclaim.

Answering the complaint:

1. Defendant admits the averments of paragraph 1

2. Defendant admits the averments of paragraph 2.

3. Defendant avers that the agreement, copy of which is annexed to the complaint, speaks for itself and refers to the same for a more complete statement of the contents thereof.

4. Defendant avers that it has made for its own use and installed at its steel works at Midland, Pennsylvania, a so-called "hot strip mill" for rolling hot metal ingots into long lengths of continuous strip, said mill comprising a single stand universal mill for rough rolling said ingots into rectangular slabs, and a single stand reversing hot strip mill for hot rolling said slabs into continuous strip, and roll tables in advance of said universal mill and between said universal mill and said reversing hot strip mill and extending beyond said reversing hot strip mill, for conveying said ingots, slabs and strip. Defendant further avers that said mill was first placed in commercial operation on or about April 1, 1949, and that between said date and shortly prior to November 30, 1951, said mill, and certain processes practiced by defendant in connection therewith, may have come within the scope of certain of the patents set forth in said agreement. Defendant denies each and every other allegation of said paragraph 4.

5. Defendant avers that for the period commencing April 1, 1949 to November 30, 1951, it paid to plaintiff all royalties due to plaintiff under said agreement. Defend-

ant denies each and every other allegation in said paragraph 5.

6. Defendant denies each and every allegation contained in paragraph 6 of the complaint.

7. Further answering said complaint, defendant avers that prior to November 30, 1951, three of the patents under which defendant was licensed by said agreement had expired and their inventions had passed into the public domain, and that prior to November 30, 1951, defendant had made certain changes and alterations in and to its said hot strip mill and in and to the process or processes employed in the operation of said mill, with the result that on or after November 30, 1951, defendant at no time made or had made for it mills and equipment coming under plaintiff's said patents, or practiced processes coming within the scope of plaintiff's said patents, or rolled steel or any other product on mills or equipment coming within the scope of plaintiff's said patents, or any of them.

Defendant's Counterclaim.

COUNTERCLAIM

8. Defendant and counterclaimant, Crucible Steel Company of America, is a corporation organized and existing under the laws of the State of New Jersey, having a regular and established place of business at Harrison, New Jersey. Plaintiff, The Cold Metal Products Company, is a corporation organized and existing under the laws of the State of Ohio, having a place of business at Youngstown, Ohio. The matter in controversy exceeds, exclusive of interest and costs, the sum of Three Thousand Dollars ($3,000.00).

9. Defendant and counterclaimant repeats all of the allegations of paragraph 3 through paragraph 7 of its Answer hereinabove set forth.

10. Defendant and counterclaimant avers that in August, 1950, certain changes were made in the price of stainless steel rolled on said hot strip mill, but that said price changes were not brought to the attention of its accounting department and accordingly, that defendant and counterclaimant reported and paid to plaintiff Nine Thousand Four Hundred and Thirty-five Dollars and twenty-four Cents ($9,435.24) in excess of the royalties due and owing to plaintiff under said agreement, in the period August 1, 1950 to November 30, 1951.

WHEREFORE, defendant and counterclaimant prays:

1. That the complaint herein be dismissed;

2. That the counterclaim herein be sustained and that judgment be given in favor of defendant and counterclaimant in the amount of Nine Thousand Four Hundred and Thirty-five Dollars and twenty-four Cents ($9,435.24); and

3. That defendant and counterclaimant be granted such other and further relief as this Court may deem just, including its costs and reasonable attorneys' fees in this action.

PITNEY, HARDIN & WARD

By s/ FRANK C. O'BRIEN

Attorneys for Defendant and Counterclaimant

744 Broad Street

Newark, New Jersey

Of Counsel:

CHARLES H. WALKER

FISH, RICHARDSON & NEAVE

20 Exchange Place

New York 5, N. Y.

RAYMOND J. McELHANNON

WARD, CROSBY & NEAL

225 Broadway

New York 7, N. Y.

Service of a copy of the within Answer and Counterclaim is hereby acknowledged this 16th day of February, 1953.

s/ O'MARA, SCHUMANN, DAVIS & LYNCH

O'Mara, Schumann, Davis & Lynch

Attorneys for Plaintiff

Plaintiff's Reply to Defendant's Counterclaim.

In reply to defendant's counterclaim, plaintiff says:

1. Plaintiff admits the allegations of Paragraph 8.

2. In reply to Paragraph 9, plaintiff admits (a) that defendant made or had made for its own use and installed in its Steel Works at Midland, Pennsylvania a hot strip mill for rolling hot metal ingots into long lengths of continuous strip, (b) that said mill comprises a roughing mill for rough rolling ingots into rectangular breakdowns or slabs, a reversing finishing mill for rolling the slabs or breakdowns into strip-like form, roll tables in advance of the roughing mill and between the roughing mill and the finishing mill and extending beyond the finishing mill for conveying the ingots, slabs, breakdowns or strip, guides, pinch rolls, and other equipment, (c) that said mill was first placed in regular commercial operation on or about April 1, 1949, (d) that, between April 1, 1949 and November 30, 1951, as well as subsequent to November 30, 1951, said mill and the rolling processes practiced by defendant in connection therewith did, in fact, come within the scope of certain of the patents set forth in the agreement of September 30, 1946, (e) that, for the period commencing April 1, 1949 and ending November 30, 1951, defendant paid certain of the royalties to plaintiff under said agreement, and (f) that, prior to November 30, 1951, three of the patents under which defendant was licensed by said agreement had expired. Plaintiff denies (a) that, for the period April 1, 1949 to November 30, 1951, defendant paid to plaintiff all royalties due to plaintiff under said agreement of September 30, 1946, (b) that the defendant made any changes or alterations in or to its hot strip mill or

in or to the processes employed in the operation of the mill resulting in the defendant being relieved of its obligation to pay royalties under said agreement, (c) that defendant, at no time on or after November 30, 1951, made or had made for it mills and equipment coming under the licensed patents or practiced processes coming within the scope of the licensed patents, or rolled steel or any other product on mills or equipment coming within the scope of the licensed patents. Plaintiff avers (a) that defendant's hot strip mill and processes practiced by the defendant in connection therewith, both prior to November 30, 1951 and subsequent thereto, were covered by and came within the scope of one or more of the unexpired patents set forth in said agreement of September 30, 1946, and (b) that such changes or alterations as defendant may have made in and to said hot strip mill or the processes employed in the operation of said mill did not modify, in any way, the essential characteristics thereof or take said mill or processes outside the scope of the claims of said licensed patents. Plaintiff denies each and every other allegation of Paragraph 9 of defendant's counterclaim not specifically covered by the foregoing admissions, denials and averments.

3. In reply to Paragraph 10, plaintiff denies each and every one of the allegations contained therein and avers that, on the contrary, defendant has failed and refused to pay all of the royalties due under said license agreement for the period April 1, 1949 to November 30, 1951, with the result that defendant still owes to the plaintiff for the period April 1, 1949 to August 31, 1951 royalties in excess of $254,867.27 and royalties for the period subsequent to August 31, 1951 in an amount not

now known to plaintiff and for which plaintiff seeks discovery and an accounting.

WHEREFORE, plaintiff prays that defendant's counterclaim be dismissed and that it be granted such other and further relief as this Court may deem proper, including its costs and reasonable attorneys' fees in this action.

EDWARD J. O'MARA
WILLIAM H. WEBB
Attorneys for Plaintiff

O'MARA, SCHUMANN, DAVIS & LYNCH
WEBB, MACKEY & BURDEN
Of Counsel

Defendant's Supplemental Counterclaim.

11. Jurisdiction of this counterclaim is founded upon 28 U.S.C. §§ 1338, 2201.

12. By notice dated March 2, 1953, and effective April 1, 1953, subsequent to February 16, 1953, when defendant's original answer and counterclaim in this action were served and filed, defendant, pursuant to and in compliance with Section XI of the license agreement of September 30, 1946, a copy of which is annexed to the complaint herein, cancelled said license agreement.

13. By notice dated July 1, 1954, plaintiff notified defendant that its continued use subsequent to April 1, 1953 of a certain steel rolling mill was charged by it to infringe United States patents 2,072,122, 2,087,065, and 2,214,107 owned by plaintiff.

14. None of the claims of the above patents have ever been infringed by defendant.

15. Each of the above patents is invalid because the subject matter of the patent was obvious at the time

the invention was allegedly made to persons having ordinary skill in the art to which that subject matter pertains, in view of the state of the art then existing.

WHEREFORE, defendant prays

1. For a declaratory judgment that United States patents 2,072,122, 2,087,065, and 2,214,107 are invalid and have not been infringed by defendant.

2. For an injunction restraining plaintiff or anyone in privity therewith from instituting any suit for infringement against defendant or anyone in privity with defendant under any or all of United States patents 2,072,122, 2,087,065, and 2,214,107.

3. For an award of costs to defendant, and reasonable attorneys' fees.

4. For such other and further relief to defendant as the Court may deem proper.

PITNEY, HARDIN & WARD
Attorneys for Defendant
By FRANK C. O'BRIEN

Dated: January 28, 1955

Of Counsel:

CHARLES H. WALKER,
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New York 5, N. Y.

RAYMOND J. McELHANNON
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225 Broadway,
New York 7, N. Y.

Plaintiff's Reply to Supplemental Counterclaim.

Service of a copy of the within Supplemental Counterclaim is hereby acknowledged this .... day of January, 1955.

O'MARA, SCHUMANN, DAVIS & LYNCH
Attorneys for Plaintiff

Plaintiff's Reply to Defendant's Supplemental Counterclaim and Plaintiff's Counterclaim.

For its reply to defendant's supplemental counterclaim, plaintiff says:

1. Plaintiff admits the allegations of Paragraph 11 of defendant's supplemental counterclaim.

2. Plaintiff admits the allegations of Paragraph 12 of defendant's supplemental counterclaim.

3. Plaintiff admits that, by letter dated July 1, 1954, it notified defendant that defendant's continued use, subsequent to April 1, 1953, of a certain steel rolling mill was charged by plaintiff to infringe United States Letters Patent Nos. 2,072,122, 2,087,065, and 2,214,107, owned by plaintiff, but avers that, as early as April, 1952, defendant was notified by plaintiff that defendant's hot rolling mill and the operation thereof were within the scope of one or more of said Letters Patent, that, subsequent to April 1, 1953 and prior to October 13, 1953, defendant was notified of plaintiff's charge of infringement of said Letters Patent by reason of defendant's continued use, subsequent to April 1, 1953, of said steel rolling mill, that, on October 13, 1953, defendant was again notified and advised of plaintiff's position that the continued use of said mill subsequent to April 1, 1953 constituted an infringement upon said Letters Patent.

and that, in the subsequent dealings between the parties looking toward a settlement of "all issues, claims and demands by Cold Metal against Crucible," defendant was apprised and aware of plaintiff's position that defendant's continued use of said rolling mill subsequent to April 1, 1953 constituted an infringement upon said Letters Patent owned by plaintiff.

4. Plaintiff denies the allegations set forth in Paragraph 14 of defendant's supplemental counterclaim.

5. Plaintiff denies each and every of the allegations contained in Paragraph 15 of defendant's supplemental counterclaim.

Counterclaim

For its Counterclaim against the defendant, Crucible Steel Company of America, plaintiff says:

6. Plaintiff, The Cold Metal Products Company, is a corporation organized and existing under the laws of the State of Ohio, having a place of business at Youngstown, Ohio. Defendant, Crucible Steel Company of America, is a corporation organized and existing under the laws of the State of New Jersey, having a regular and established place of business at Harrison, New Jersey. The matter in controversy exceeds, exclusive of interest and costs, the sum of Three Thousand Dollars.

7. The jurisdiction of this Court is founded on the fact that this counterclaim constitutes an action arising under the Patent Laws of the United States for infringement of United States Letters Patent, and on Title 28, United States Code, Section 1338. Venue is based upon Title 28, United States Code, Section 1391.

8. Plaintiff, for some years past and at all times hereinafter complained of, was and now is the owner of the entire right, title and interest in and to each of the following United States Letters Patent and any and all rights of recovery for infringement thereof:

Patent No.	Patentee	Date of Issue
2,072,122	Montgomery	March 2, 1937
2,087,065	Montgomery	July 13, 1937
2,214,107	Montgomery	September 10, 1940

9. On or about September 30, 1946, plaintiff and defendant entered into a license agreement whereby plaintiff granted to defendant a nonexclusive right and license under certain United States Letters Patent, including the patents set forth in Paragraph 8 hereof, (a) to make, use and have made for its own use mills and equipment coming under said Letters Patent, (b) to own and use said mills and equipment, (c) to practice processes coming within the scope of said Letters Patent throughout the United States, its territories and possessions, and (d) to use and sell the products of such mills, equipment and processes. In return for the rights granted by plaintiff to the defendant, defendant agreed to pay to plaintiff certain royalties on products rolled on mills or equipment under said Letters Patent, as set forth in Section III of said agreement.

10. Pursuant to the rights granted to it under said agreement, defendant made or had made for its own use a two-stand reversing hot rolling mill and equipment coming under certain Letters Patent recited in said agreement, including the patents identified in Paragraph 8 hereof, and has used and continues to use said mill and equipment, and has practiced and continues to practice

processes coming within the scope of the Letters Patent identified in Paragraph 8 hereof, and has used and sold and continues to use and sell the products of said mill, equipment and processes. For the period from April 1, 1949 to November 30, 1951, defendant paid to plaintiff certain royalties asserted by defendant to be due, pursuant to the terms of said license agreement. From and after November 30, 1951, defendant, although it has continued to use said mill and equipment coming under said Letters Patent set forth in Paragraph 8 hereof, and has practiced and continues to practice processes coming within the scope of said Letters Patent, nevertheless, failed and refused to pay to plaintiff the royalties due, pursuant to the terms of said agreement, prior to April 1, 1953.

11. By notice, dated March 2, 1953 and effective April 1, 1953, defendant cancelled said license agreement, but, nevertheless, since April 1, 1953, has infringed upon each of said Letters Patent identified in Paragraph 8 hereof by using said hot rolling mill and equipment, which embodies inventions covered by said Letters Patent, and by using processes or methods covered by said Letters Patent, and is still infringing upon said Letters Patent No. 2,214,107 and will continue to do so unless enjoined by this Court.

12. Plaintiff and its predecessor have placed the required statutory notice on all mills manufactured and sold by or for them under said Letters Patent and plaintiff has given both written and oral notice to defendant of its infringement thereof; but, despite such notices of infringement, defendant has persisted in its infringement upon said Letters Patent.

13. The inventions of each of said Letters Patent are of great utility and value and have been extensively applied to practical use by defendant and by others. The inventions of said Letters Patent have effected a marked advance in the metal rolling art and the public generally, and particularly this defendant, have benefited greatly thereby. Licenses have been granted by plaintiff and its predecessor under the inventions covered by said Letters Patent to various steel manufacturers, including this defendant, and said licensees have paid substantial sums thereunder.

WHEREFORE, plaintiff prays:

A. For both preliminary and final injunctions against further infringement of said Letters Patent No. 2,214,107.

B. For an order holding each of Letters Patent Nos. 2,072,122, 2,087,065 and 2,214,107 valid and infringed by defendant.

C. For an accounting of profits and damages arising out of defendant's infringement of each of said Letters Patent Nos. 2,072,122, 2,087,065 and 2,214,107.

D. For an award of costs to plaintiff, including reasonable attorneys' fees.

E. For such other and further relief as the Court may deem proper.

THE COLD METAL PRODUCTS COMPANY
By EDWARD J. O'MARA
WILLIAM H. WEBB
Attorneys for Plaintiff

Defendant's Reply to Plaintiff's Counterclaim.

Defendant's Reply to Plaintiff's Counterclaim

Defendant, CRUCIBLE STEEL COMPANY OF AMERICA, for its reply to the counterclaim contained in plaintiff's reply to defendant's supplemental counterclaim, dated February 15, 1955, and filed herein February 16, 1955, alleges as follows:

1. Defendant admits the allegations of paragraph 6.

2. Defendant admits the allegations of paragraph 7.

3. Defendant is without knowledge or information sufficient to form a belief as to the truth of the averments of paragraph 8.

4. Replying to paragraph 9, defendant admits that it entered into a license agreement with plaintiff on or about September 30, 1946, but avers that the agreement, a copy of which is annexed to the complaint, speaks for itself and refers to the same for a more complete statement of its contents.

5. Replying to paragraph 10, defendant admits and avers that it made or had made for its own use and installed at its steel works at Midland, Pennsylvania, a so-called "hot strip mill" for rolling hot metal ingots into long lengths of continuous strip, said mill comprising a single stand universal mill for rough rolling said ingots into rectangular slabs and said slabs into relatively long and thin breakdowns, and a single stand reversing hot strip mill for hot rolling said breakdowns into continuous strip, and roll tables in advance of said universal mill and between said universal mill and said reversing mill and extending beyond said reversing hot strip mill, for conveying said ingots, slabs, breakdowns and strip. De-

fendant further avers that said mill was first placed in commercial operation on or about April 1, 1949, and that between said date and shortly prior to November 30, 1951, said mill and certain processes practiced by defendant in connection therewith, may have come within the scope of certain of the patents set forth in said agreement. Defendant further avers that prior to November 30, 1951, defendant had made certain changes and alterations in and to its said hot strip mill and in and to the process or processes employed in the operation of said mill, with the result that on or after November 30, 1951, defendant at no time made, or had made for it, mills and equipment coming under or covered by plaintiff's said patents, or practiced processes coming within the scope of plaintiff's said patents, or rolled steel or any other product on mills or equipment coming within the scope of plaintiff's said patents, or any of them. Defendant further avers that for the period April 1, 1949 to November 30, 1951, it paid to plaintiff all royalties due to plaintiff under said license agreement and that no royalties accrued under said agreement for defendant's operations subsequent to November 30, 1951. Except as herein admitted or averred, defendant denies each and every allegation in paragraph 10 of plaintiff's counterclaim.

6. Replying to paragraph 11, defendant admits that by notice, dated March 2, 1953, and effective April 1, 1953, it cancelled said license agreement, and avers that such written notice was pursuant to the terms of Section XI of the said license agreement. Defendant denies each and every other allegation contained in paragraph 11 of plaintiff's counterclaim.

– Defendant's Reply to Plaintiff's Counterclaim.

7. Defendant is without knowledge or information sufficient to form a belief as to the truth of the averment of paragraph 12 of plaintiff's counterclaim that plaintiff and its predecessor have placed the required statutory notice on all mills manufactured and sold by or for them under the patents in suit; defendant admits that written notice of defendant's alleged infringement of the three patents here in suit was given by plaintiff by letter dated July 1, 1954. Defendant denies each and every other allegation of said paragraph 12.

8. Replying to paragraph 13, defendant admits that it entered into the license agreement with plaintiff dated September 30, 1946, a copy of which is annexed to the complaint, and paid plaintiff substantial sums thereunder. Except as to the said license agreement between plaintiff and defendant, defendant is without knowledge or information sufficient to form a belief as to the truth of the averment of paragraph 13 of plaintiff's counterclaim that licenses have been granted by plaintiff and its predecessor under one or more of the patents in suit to steel manufacturers and that said licensees have paid substantial sums thereunder. Except as herein expressly admitted, defendant denies each and every allegation of said paragraph 13.

Further Replying to Plaintiff's Counterclaim

9. Defendant avers that each of the three patents identified in paragraph 8 of plaintiff's counterclaim, is invalid and void because:

(a) The alleged invention thereof was known or used by others in this country, and was patented or described in printed publications be-

fore the invention thereof by the applicant for said patent;

(b) The alleged invention thereof was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for said patent;

(c) The applicant for said patent did not invent the subject matter claimed therein;

(d) Before the applicant's alleged invention of said patent, the same was made in this country by another who had not abandoned, suppressed or concealed it; and

(e) At the time of the alleged invention of said patent, the same was obvious to persons having ordinary skill in the art to which the subject matter of said patent pertains.

10. Defendant avers that each of the three patents identified in paragraph 8 of plaintiff's counterclaim is invalid and void for the following additional reasons:

(a) As to each of said patents because the claims thereof are indefinite, ambiguous and uncertain and do not particularly point out and distinctly claim the part, combination, process or improvement which the patentee claims as his alleged invention or discovery;

(b) As to patent 2,072,122 because the claims thereof are functional and purport to monopolize exhausted combinations of elements;

(c) As to patents 2,214,107 and 2,087,065 because the claims thereof cover obvious manipulations of machines disclosed in prior patents to others, and because said claims, if construed to cover defendant's operations, are directed to subject matter not disclosed or claimed in the application for said patent as originally filed; and

(d) As to each of said patents, because the claims thereof purport to monopolize mere aggregations of elements or process steps.

11. As to each of the three patents identified in paragraph 8 of plaintiff's counterclaim, defendant avers that by reason of the proceedings in the United States Patent Office during the prosecution of the application which resulted in each said patent, and by reason of the admissions and representations therein made by or on behalf of the applicant in order to induce the granting of said patent, and by reason of the revisions in the scope of claims made therein in avoidance of prior art citations, plaintiff is estopped to claim for said patent, a construction, were the same otherwise possible, such as would cause said patent to cover or include the acts of defendant of which plaintiff complains.

12. Defendant avers that the claims of each of said patents in suit, even if valid and if given whatever scope the art permits, do not cover the apparatus and the methods used by defendant and complained of herein.

Defendant's Reply to Plaintiff's Counterclaim.

WHEREFORE, defendant prays

1. For a declaratory judgment that United States patents 2,072,122, 2,087,065, and 2,214,107 are invalid and have not been infringed by defendant.

2. For an injunction restraining plaintiff, or anyone in privity with plaintiff, from instituting any suit for infringement against defendant, or anyone in privity with defendant, under any or all of United States patents 2,072,122, 2,087,065, and 2,214,107.

3. For an award of costs to defendant, and reasonable attorneys' fees.

4. For such other and further relief to defendant as the Court may deem proper.

PITNEY, HARDIN & WARD
Attorneys for Defendant
By FRANK C. O'BRIEN

Dated:

Of Counsel:

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New York 7, New York

Portions of the Transcript of Proceedings.

OPENING STATEMENT OF DEFENDANT.

[54] *Mr. Walker*: In other words, if your Honor were to take any one of these patents and just take it into a germ proof room, and read it, and not have any knowledge of what its place in the art was, you might think, as Mr. Webb would like to have you, that this is really a pretty clever mill; it is the first mill, says he, on which it was possible to roll material of such and such a character. So that if you were to fall into his little trap of thought and read the patent in that sense you might very well feel, as he would like to have you, that it isn't a difference of any substance to transfer part of the function of what was once a pinch roll having a pinch and a low lift and an upper lift position, transfer the function of the low lift to another adjacent roll. You might very well so believe, and you would be right, if it was a basic pioneer patent whose discovery and invention consisted in the idea of having a pinch roll in a pinch position, and at another time in a partially retracted position, and at still another time in a more fully retracted position.

* * * * * * *

STIPULATIONS OF COUNSEL.

[74] *Mr. Webb*: Now, your Honor, defendant has admitted in its trial brief, and we have set forth in the stipulation, which will more properly come in at the time of defendant's case that the plaintiff, Cold Metal, has the entire right, title and interest in and to each of the patents which have just been marked in evidence and of any and all rights of recovery.

Mr. Walker: Subject to correction if error be made to appear.

Stipulation of Counsel.

Mr. Webb: That is correct.

And defendant in its trial brief has admitted, and I [75] think it's agreed here, first, that Crucible installed a hot strip mill under the license agreement and placed it in commercial application on April 1, 1949.

Mr. Walker: On or about.

Mr. Webb: On or about April 1, 1949, and it is admitted and it is agreed here that on that mill and its operation under the agreement Crucible paid the royalties specified now in Paragraph 1 of the stipulation appearing as Exhibit P-1, and I think that it is also agreed here, is it not, Mr. Walker, that Crucible ceased paying royalties under the agreement on November 30, 1951.

Mr. Walker: That is my understanding that the last royalty payment tendered covered the calendar month of November, that ended November 30, 1951.

• • • • • • •

[77] It is admitted in defendant's trial brief and is agreed here, is it not, Mr. Walker, that no further royalties were paid under the agreement for the period subsequent to November 30, 1951 ?

Mr. Walker: That is right.

• • • • • • •

[78] *Mr. Webb*: And that the agreement of September 30, 1946, continued in full force and effect until April 1, 1953, at which time the agreement was canceled pursuant to the right to cancel given to Crucible by Section 11 of the agreement.

Mr. Walker: That's right.

• • • • • • •

WILLIAM B. LOCKWOOD

[223] WILLIAM BRUCE LOCKWOOD, called and sworn on behalf of the plaintiff, testified as follows:

The Clerk: May we have your full name, please, sir.

The Witness: William Bruce Lockwood.

The Clerk: Your address for the record.

The Witness: Poland, Ohio.

DIRECT EXAMINATION

By Mr. Webb:

Q. What is your age, Mr. Lockwood?

A. I am 65 years of age.

Q. By whom are you employed?

[224] A. I am employed by the Cold Metal Products Company.

Q. What is your present position?

A. I am president.

Q. How long have you been president?

A. Since January, 1946.

Q. Prior to the time that you were president, what position did you hold?

A. I was general manager prior to that time.

Q. And have you performed the duties of general manager also during the time that you have been acting as president?

A. Yes.

Q. Will you tell us briefly the business of the Cold Metal Products Company, Mr. Lockwood?

A. The Cold Metal Products Company is a producer of cold rolled strip steel, especially special qualities

of cold rolled strip steel, and also manufactures cold mills and certain auxiliary cold mill equipment.

* * * * * * *

CROSS EXAMINATION

[241] Q. Where did the Cold Metal Products Company come into the picture?

A. The Cold Metal Products Company came in in the early part of the 1940s as the operating end of the business; it was a wholly owned subsidiary of the Cold Metal Process Company, and the Products Company took care of the manufacture of the mills and of the cold roll strip business.

Q. Yes.

A. (Continuing) Which by that time had grown to substantial proportions.

Q. Yes. That left the Cold Metal Process Company, the original company, as a patent holding and licensing company and left the business of mill manufacture, demonstration and disposition of cold rolled product to the Cold Metal Products Company?

A. The Products was the operating end of the business.

* * * * * * *

[257] Q. Did you personally participate at all in the negotiations leading up to the license agreement between the parties here?

A. No.

Q. Did you participate in the sense that you sat in a capacity in which you had reported to you the results of [258] discussions and had to make decisions whether to accept or reject various proposals in regard to the agreement?

A. If there were any discussions, there were very

few, I don't recall distinctly. Mr. Webb handled that matter.

Q. I see.

A. My recollection was that—of course, we approved what Mr. Webb did, but I don't recall any discussions.

Q. Well, at that time had your company issued very many licenses under the reversing hot mill patents, you had issued several licenses at that time, had you not?

A. You are speaking of the Products Company?

Q. Either or both, the Process or Products.

A. There have been half a dozen, or more, maybe ten.

* * * * * * *

RALPH A. FREED.

[290] RALPH A. FREED, called and sworn on behalf of the plaintiff, testified as follows:

DIRECT EXAMINATION

By Mr. Webb:

* * * * * * *

Q. By whom are you employed?

A. At the present time, the Cold Metal Products Company.

Q. And what position do you hold at the present time with Cold Metal Products?

[291] A. Engineer.

Q. And how long have you been with the Cold Metal Products?

A. Well, with the Cold Metal Process, and then slid over into Cold Metal Products, it's been since May, 1930.

Q. And what has been the nature of the work, in

a general way, that you have done with Cold Metal Process and Cold Metal Products since you first went there?

A. It's been general mill engineering, primarily on hot mill work, but considerable on cold mill work, and any special equipment that was being used, or the company would want designed.

Q. General engineering work—

A. Yes, sir.

Q. —would that describe it?

A. I think so.

Q. And did you work on the initial hot mill installation which is being referred to here as being the installation at Briar Hill plant of the Youngstown Sheet & Tube Company?

A. I did.

* * * * * * *

[293] Q. I will rephrase my question. Mr. Freed, would you please tell us the general nature of the work that was done at the Briar Hill plant of the Youngstown Sheet & Tube Company in connection with reversing hot mills?

A. It was an attempt to prove out and test out a theory that had been advanced in a new method, new procedure of rolling hot strip on a single stand reversing mill by the use of pinch rolls and hot coilers on each side of the reducing mill.

Q. Were you actively engaged in that work?

A. To a quite considerable extent, yes.

Q. Was there any further work done on reversing the hot mill in the plants of Youngstown Sheet & Tube Company besides that done at the Briar Hill plant, to which you have referred?

A. Yes. After it was fairly well established that it was possible and we did roll some strip from a slab down to strip gauge, the Sheet & Tube, as well as our own company, wanted to be certain that they were able to roll from a full sized ingot direct into strip on one reversing mill. So that's the experiment they set up and worked out at the Campbell Works of the Youngstown Sheet & Tube.

Q. Are both the Briar Hill works and the Campbell Works located at Youngstown, Ohio, or in that vicinity?

A. They are, yes.

Q. You referred to Sheet & Tube in one of your last answers; is that the shorthand version of the name of the [294] company, Youngstown Sheet & Tube Company?

A. It is, it is the abbreviated form.

Q. What was the nature of the work that you did, yourself, in connection with the work done at Briar Hill and at Campbell? Tell us a little more in detail.

A. Well, the work on the Briar Hill plant consisted of two things. I did considerable of the engineering work, such as designing and changing and altering the different types of guides, did work on the pinch rolls as to change them so that they would work more satisfactorily, and it was considerable all around engineering that would be necessary in a development of that kind. Then also, on a number of their experimental and trial runs I would be out and assist Mr. Montgomery and other men there to run these tests and try out the mill and find out what the bugs were in it so that I would be in better shape to help them eliminate them the next few days afterwards.

Q. Could you give us some idea as to the percentage of the slabs which you attempted to roll on the Briar Hill installation which you actually did succeed in rolling?

A. Of course, we were depending upon the Youngstown Sheet & Tube to furnish us with the heated slabs, so when we thought we had everything lined up properly we would notify them ahead of time that we would want maybe six or eight slabs, that we figured we would be able to roll. So we would start our rolling and they would bring one down and we would attempt to roll it [295] back and forth to get it to coil. Some days maybe we wouldn't get any that would come down to what would be considered hot strip gauge, other times we would. So I would say that on an average, if we could get out of the six or eight slabs that we had ordered, if we could get one that we could roll down to a hundred-thousandth, or a little more, and get it down the table without coiling [cobbling] it, we were well satisfied, but that was about the average, one out of six or eight that we would order.

Q. What were some of the principal difficulties which you were having in connection with this work that was done at the Briar Hill plant?

A. Well, the main thing—it constituted two things, that is, both mechanical and electrical. We had some big, cumbersome pieces of machinery there, your mill, your tables, your pinch rolls and your coilers, that all have to be synchronized together so that they will all reverse in one way and then they will change directions together, and we would have quite a bit of electrical trouble in those early days as to getting those properly synchronized so they would function together

properly. It was natural if one was a little bit slower than the other and you would try to roll a strip, why you would run into a cobble, it would give you trouble. Then our pinch rolls, we had considerable trouble on them.

The Court: Tell me, what is that word?

The Witness: Pinch rolls, the pinch rolls that come [296] down and pinch it through.

The Court: Pinch rolls, yes.

A. (Continuing) We had difficulty on those because on some of the strip when the pinch rolls would come down on it it would slit, instead of pushing it on in, it would slit. So we had quite a bit of trouble on that, and some on our reels, and the side guides, I suppose we tried half a dozen different types of side guides, guiding it in before we could get something that would work satisfactorily. Now, those are just some of the things that we ran into.

Q. Were those also problems that you ran into in connection with the work at Campbell when you were trying to roll direct from an ingot?

A. Yes, primarily, but we had partially solved some of the problems out there and we gained by that knowledge, but there were others that came up, since we were starting with a much bigger ingot than we were out at Briar Hill.

Q. As I understand it, at Briar Hill you were starting with the slab and at the Campbell Works you were starting with an ingot?

A. That's right.

Q. In each instance you were trying to roll down to the finished strip?

A. That is right.

Q. Did you have difficulties in the handling of the [297] material during the carrying on of this work at Briar Hill and Campbell?

A. Oh, yes, we had considerable on that.

Q. Over what period of time did this work at Campbell and Briar Hill extend, Mr. Freed, if you can give us that?

A. I think it was some time in the middle or the late 1930s that I first started in on it, and then it was the period, I suppose, two, maybe three years.

Mr. Webb: May I have that answer read?

(Answer read by the reporter.)

The Witness: On the engineering work. It may have been a year later than that, I just don't remember. I know I had only been with the company a comparatively short time.

Q. When did you go with the company?

A. 1930.

Q. 1930?

A. Yes.

Q. I believe you said in your last answer the middle or late 1930s; did you mean the early 1930s?

A. No, I meant the middle or latter part of the year 1930.

Q. I am sorry.

A. It was the latter part, middle or latter part of the year 1930.

[298] Q. Thank you. And for how long a period did the work at Briar Hill and Campbell extend, Mr. Freed, from the time you started on it until—

A. Somewhere around three to four years.

. . . . . .

[336] Now, when we want to bring the material into the mill it is quite important that you get that in on the center of the mill, right on the path, because if it comes in a little bit crooked it will want to turn and get a camber and angle off. Then when you try to coil it in the coiling furnaces it gets a very wobbly, loose coil up there, it won't be coiled up straight. And then when you try to get it off it weaves back and forth and it gives you all kinds of trouble.

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[389] Q. Would you please describe for us the functions performed by the pinch rolls of the original mill, bearing in [390] mind the three positions?

A. Of course the most important function of the pinch roll is when it is in its pinch position to perform two duties, to drop down on the strip and try to hold the end of it and retain it between the working rolls and the pinch rolls, and then as it is reversed to feed the end of this strip back in the mill. Of course the upper roll, when it is in its up position is merely to be out of the way of everything. Then at its low lift position it acts as a roller guide to the strip.

Q. Well, before going to the low lift position may I ask you whether when in the pinch position the pinch roll also performs the function of pulling the strip off the reel? That is, when you have the pinch rolls in the pinch position, do they pull this strip off the roll [reel] in feeding it back?

A. They pull the strip off the reel and feed it into the work rolls of the mill.

Q. So that in the pinch position, as I understand you testimony, the pinch rolls pull the strip off the reel and also feed it toward the mill?

A. Yes, sir.

Q. I believe you mentioned yesterday that the lower pinch roll functions, also as a table roll, is that correct?

A. It does.

[391] Q. All right. Now, in the high lift position what are the functions of the pinch rolls?

A. It is merely to be out of the way of everything so that there is free access along the table rollers to pass any material underneath that you wish.

Q. And, of course, while your upper pinch roll is in that position does your lower pinch roll serve also to carry the strip?

A. Yes, it performs that function.

Q. All right. Now let's go to the low lift position, and describe for us, please, the several functions of the pinch rolls in the low lift position.

A. When the pinch rolls are in that low lift position there are several functions that it performs. One of them is to keep the strip down fairly close to the table rollers so that it will be in and over the overhanging flanges of the side guides. Now, I think there is a drawing here that will show you the shape of those side guides.

On drawing No. 6, down in the lower righthand corner, you can see those kind of "U" shaped sections there with the opening in towards the center. Well, that is the shape of your side guides.

So you want to keep the material down close enough to the table rollers that it won't bounce up and hit that top overhanging flange on those side guides. Now, that is [392] a very important function.

Q. Would that be considered as a vertical guid-

ing action, guiding it so as to hold it in proper position in the vertical plane?

A. Yes, that could be so explained.

The Court: Just a minute, please.

The Witness: Yes, sir.

(Discussion between Court and witness, off the record.)

Q. Now, you have spoken about this function of holding the material down between the guides, this vertical guiding action. Tell us the other function, please.

A. It also has another function. Due to its frictional resistance it will maintain, or assist in maintaining the strip in the center so it won't be apt to float so much.

And then there is another—

Q. Wait just a moment. While you are on that one, just so it is clear, as I understand it, when it is in the low lift position your strip is in contact with the roll, is it?

A. Yes.

Q. And as a result of the strip passing over the roll there is friction and that prevents that strip from weaving sidewise?

A. It would assist it, yes.

[393] Q. So you have that horizontal guiding action also performed in that low lift position?

A. You see, the strip is under tension between the unwinding reel and the mill. It is coming off of this spool a little slower than the mill is taking it up. It is a very definite purpose there, so it will come off straight and won't flop over inside. So there is a little

tension in there, in between that. So this roll holding it down does have a tendency to want to keep it, due to its friction—to keep it from going sideways.

Q. Is that of any importance in preventing it from going sidewise?

A. Yes, because you want to keep it either going into the mill or into the roller as steady—so it will pile up in the center of the reel, or enter and retain its position on the center of the mill.

Q. If you don't guide it properly into the reel, do you run into any difficulties?

A. Yes, you have a lot of difficulties holding it there, and getting it off, and getting it back through the mill. It might cause a lot of trouble.

Q. If you don't have it entering into the mill properly, and have it moving sidewise, sliding sidewise, what sort of difficulties does that create?

A. It creates a very bad camber in the strip, and then [394] try to get it back in on the next pass.

Q. All right. Now, what are the additional functions, Mr. Freed?

A. There is another function it performs. The distance from the deflector roll under the furnace and the reducing rolls is quite considerable. And you get —as long as this material is flowing through they keep it as well synchronized as possible, but there is a little variation, and your strip going in at that speed will have a tendency to want to whip up and down, and by holding it down at that position it takes practically all of that whip out of the strip, so that it can be held down pretty close to your pass line, and enter your mill on a smooth, steady path instead of jumping

up and down, whipping up and down. So it also serves that function.

And then also—

Q. Before we leave that one, if you had any substantial bounce, would that give you any difficulties?

A. Oh, any time there is any bouncing or jerking you have difficulties on your rolling and on your coiling in your furnace, yes—the reels in the furnace.

Q. How about the possibility of hitting the upper portion of the guides, if you had any of that bounce?

A. Be very apt to, yes.

Q. Now, what other functions are there?

[395] A. That cylinder that operates that pinch roll also acts as a cushioning effect, so that if there is a little excess flop, or jump, or pressure up on to that, it will cushion it, so as to try to maintain your tension between the material that is being paid off of the reel and into the mill as uniform as possible.

Q. In other words, if you have that in the low lift position you have sort of a cushioning effect there and, as a consequence, it assists in giving you a uniform tension between the mill and the coiler, is that what you said?

A. That is right, yes.

Q. And what other functions are there that you recall? Have you mentioned the matter of looping?

A. No. Again, it is sometimes a little difficult to have your equipment so properly synchronized that everything will function just perfectly right, and if, by chance, when you have your reel wanting to feed the material to the mill just a little faster than it is taking it away, it gets loose and sloppy in there, and there is the danger that it might fold over, clear over,

by the time it gets up to the mill, and if you would attempt to roll it back you would have a cobble and possibly a broken roll.

But with this roll down here, a short distance away, if you do have any of these folds, it would come up against [396] that and iron those folds out, before it would get to the mill, and it would give the roller an opportunity to see that things weren't functioning just properly, and he may have to stop the mill long enough to make those adjustments.

Q. If you get one of those folds in the mill, what happens?

A. Well, it is a decided cobble. More than likely it will break your rolls.

Q. Would you describe for the Court what you mean by a cobble? That term has been used a couple of times, but I think it might be well to describe it.

A. Any time any difficulties occur in rolling where that you are unable to finish the complete rolling cycle down to gauge, or if it would go into a side guide, and dig in there, or if it would fold up, or any source of trouble where you would have to stop the material into the mill, and you couldn't go on any further, that is considered a cobble. That material has to be cut out there and thrown away. You cannot continue to roll it down to gauge, so that it is wasted.

Q. Do you have that likelihood of this looping or buckling condition that you spoke of earlier on the exit side of the mill as well as on the entry side?

A. Yes, it could happen on either side.

[397] Q. And if you had it on the exit side, what effect would your roll in the low lift position have on it?

A. Have a tendency to try to iron it out a little bit so that it could go into the coiler.

Q. It would tend to keep those loops between the low lift position and the mill so as to keep them from going into the coiler; is that what you meant?

A. Yes.

Q. Now, would you please tell us the functions of the auxiliary roll in the modified setup when it is in the low lift position?

The Court: What is that drawing over there?

The Witness: That is drawing No. 8, your Honor.

Mr. Webb: I just put it up because it shows the auxiliary roll, your Honor.

Q. Let's take a look at Drawing 20, for example, because it shows the auxiliary rolls on both sides in the low lift position.

A. Well, I would say that it performs exactly the same functions, the same purposes, as the pinch rolls in its low lift position.

Q. In other words, that auxiliary roll, when it is in the low lift position, performs exactly the same functions as the pinch roll in its low lift position?

[398] A. Yes.

Q. Is there any difference between the two setups in regard to any of these other functions that you have spoken of?

A. None that I have observed, because I have seen some very successful operations of that mill when they just had the pinch rolls, and I have seen the same very successful operations of that same mill since they have made these changes.

Q. Now, you have spoken about the auxiliary roll in the low lift position performing the same functions as the pinch roll in the original installation in its low lift position. Does it perform those functions in the same way as the pinch rolls in the original installation?

A. Yes.

* * * * * * *

CROSS EXAMINATION

[449] Q. When did you first encounter a mill, Mr. Freed, in which there was provision for lifting the pinch rolls to a low lift or a nigh lift position at the option of the operator?

A. Due to the experience we gained on the Briar Hill mill, where we only had the two positions, the up position and the pinch position, we found that dropping that a distance of eight or nine inches, something similar to that, down on the roll, that heavy weight dropping was creating quite an impact and causing considerable damages on our bearings. About that time we were working on the mill for the Dominion Foundry & Steel in Hamilton, and in that case it was a universal mill and they were going to start from ingots approximately 14 inches thick. So that meant we were going to have a drop of 16 or 18 inches, something like that. Well, that dropping that much farther led us to believe that we were going to run in a lot more damage to the equipment by [450] dropping it that far with that much weight. So we devised a method whereby we could have that pinch roll clear up out of the way during all of the slabbing operation on the ingot and everything down until it got about three-quarters of an inch or an inch thick. Then automatically the control of that was switched from the one set of cylinders over to the short stroke cylinders and then

that brought that roll down to the low lift position so it would only drop a very short distance. It gave us a little quicker operation and less damage to the equipment.

Q. The mills that you worked on prior to that time just had the pinch rolls capable of being in either the pinch position or in a position that was elevated sufficiently to let pass back and forth whatever the thickness material was that was ever rolled?

A. Well, the only mill of that sort was this experimental mill at the Briar Hill Steel.

Q. What was the situation at the Campbell Works?

A. That was the same, experimental rolling.

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[483] Q. Now, I would like to understand a little more fully than I do what you mean when you say that the pinch rolls engaging the strip between the mill and the point of coiling, or uncoiling, broke up the tension. I think that was your phrase.

A. If you had a coiling reel that is overrunning, or running just a little faster than the mill, and there was nothing to interrupt it in between, it would exert uniform tension from the reel to the mill. But if in the meantime you put a pair of pinch rolls, or anything pressing down very severely on the middle of that strip between the mill and the reel you would have considerable different tension, as we noticed out there at Briar Hill, because occasionaly, if things were not being just absolutely a hundred per cent synchronized, the reel would feed off just a little faster than the mill could be taking it away, and being held there by the pinch rolls it would have a tendency to want to fold up, and

loop, and get wavy between the reel and the pinch rolls, while it would still be tight between the pinch rolls and the mill. That was one of the conditions we had to try to overcome.

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[488] Q. Now, going back again to our initial situation, in which nothing touched the strip from the mill to the coiling reel, and the tension consequently was uniform throughout the length, when you put a pair of pinch rolls in contact with the strip, isn't it true that if you drove those pinch rolls with an external source of power at a speed corresponding exactly with the speed of the passing strip that they would not interfere with or break up the uniformity of tension which theretofore existed?

A. I doubt if it would be possible to set up any drive that at all times could give you that exact uniformity of motion of the roll with the strip.

Q. So that as a practical matter it would be difficult to drive the rolls at precisely the right speed, but if you did drive them at that speed then they would not interfere at all with the uniformity of tension, is that right?

A. That is just a little too technical. I wouldn't [489] want to commit myself definitely on it; no, sir.

Q. Can you think of any reason why they would disrupt the uniformity of tension if their external drive was such that they were wanting to move and being moved at precisely the speed of the strip at the point at which the rolls engaged it?

A. There is bound to be a certain amount of friction due to the compressing of that pinch roll on to the

mill [strip], a slight deformation of the strip. It might be very slight, but it would be there.

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[490] Q. Now, wasn't it that interference with uniformity of tension between the mill and the winding reel which the pinch rolls caused, if they were left in engagement with the strip, that was the reason for Montgomery's desire to withdraw the pinch roll to its low lift position, and thus free the strip from that factor, tending to break up the uniformity of tension?

A. I do recall—I know of discussion on that when we were having some trouble there at Briar Hill, the overrunning of the reel, it was giving us a little trouble and a comment was made, "Well, we will have to do something in the future mills to overcome that condition." Now, that may have been the outcome of his desire then to raise that roll.

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[513] Q. "In accordance with the present invention, however, I utilize the pinch rolls only while starting the leading end of the breakdown ough the mill and into the coiling reel on the opposite side, the pinch rolls being thereafter retracted, freeing the strip between the mill and the reel."

Don't you understand that the same as I do to mean that the pinch roll is retracted until such a point as to be out of contact with the strip?

A. No, sir. I would interpret that that it is freeing it from that pinching action so that the strip would be free to float clear from the mill to the reel.

Q. Well, I invite you to call our attention to anything in the text of either this, or any of the other Montgomery patents, to support your position.

A. I am merely putting my own interpretation, as I see it as an engineer. That is all I can do.

Q. Wasn't it your understanding that Montgomery's—an important purpose he had in retracting that pinch roll, so as to free the strip between the mill and the reel, was to prevent the pinch roll from having such a contact with the strip as to interfere with the uniformity of tension which would otherwise exist between the coiler and the mill?

[514] A. Of course, I have no way of knowing what Mr. Montgomery had in his mind, but I would say that that would be one of the functions of raising it, to eliminate some of that trouble that we had on the original mill, by the loose folding, loose, floppy coils, between the reel and the pinch rolls.

Q. Would you mind taking a look at page 4 of this Patent 107, Column 2, line 43, where it says—

A. What line, please?

Q. Page 4, Column 2, line 43. "The pinch roll 88 on that side is thus lifted from the material." Now, with that additional light on the question of what Montgomery's purpose or intention and operations were, isn't it clear to you that it was his purpose and intent to withdraw that pinch roll to such a point that it was no longer in contact with the material?

A. I wouldn't put that interpretation on it; no, sir.

Q. Then a little further down in that column, line 56, where it says, "The cylinders 82 on the exit side of the mill thus operate to raise the associated pinch roll from the strip." Doesn't that give you the idea that he intended to have the pinch roll removed from physical contact with the strip?

A. No, I don't, because he certainly would know that it would have to be raised more than an inch and a half [515] to free it so that it would have no frictional contact with the strip whatsoever.

Q. And then the next sentence, "The strip is thus free between the winding and unwinding coilers except where engaged by the mill." Doesn't that give you the idea that the strip is not to be in contact with this pinch roll after its retraction.

A. I would say that it would be free from any pinching action and not physical contact.

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DR. GEORGE SACHS.

[557] GEORGE SACHS, called and sworn on behalf of the plaintiff, testified as follows:

The Clerk: May we have your full name, please, sir?

The Witness: George Sachs, S-A-C-H-S.

The Clerk: And your address for the record?

The Witness: 103 Bradford Lane, Syracuse, New York.

DIRECT EXAMINATION.

By Mr. Webb:

Q. Doctor, will you please state your age?

A. I am 60 years old.

Q. And are you connected with Syracuse University at the present time?

A. That is correct.

Q. What is your connection with the university?

A. I am Associate Director of Syracuse University Research Institute and Professor of Metallurgy.

* * * * * * *

[565] Q. Doctor, are you familiar with the Crucible hot strip mill, which is in issue here?

A. Yes, I have seen that mill twice.

Q. And was it in operation when you saw it?

A. Yes, it was both times in operation.

Q. And have you inspected and studied operations on similar reversing hot strip mills?

A. I have seen two more reversing hot strip mills in Germany, a mill at the plant of Hoesch, and another very modern mill at a plant of Capito & Klein, which is a Krupp concern.

Q. And have you studied the drawings of Crucible's mill, both the original and the modified mill, which constitute Exhibit P-16, these large drawings?

[566] A. Yes.

Q. Well, referring to the original mill, doctor, and particularly to the pinch roll setup, would you please state some of the functions performed by the pinch rolls in the different positions they occupy?

A. Well, the pinch roll in this mill is not a conventional or simple pinch roll as the term was usually applied in the previous days; it is a much more complicated piece of equipment which has also considerably more function.

Originally the pinch roll was just used in the pinching position for supplying material to some other piece of equipment. There are many such applications, including this rolling mill application.

Now, the new pinch roll has a number of additional functions, which are illustrated or which are effected by what is called the three different positions; namely, the pinch position, the low lift position and the high lift position of this roll.

In addition, the lower pinch roll, as such, is a table roll, or vice versa, a table roll is utilized as the lower pinch roll, and has also all the functions which a table roll in a rolling mill has. It works in synchronized fashion with all the other table rolls—the lower pinch roll.

[567] Shall I continue to describe those functions?

[568] Q. Yes. Will you please, Doctor, go ahead?

A. Now, in the pinch position the pinch roll also has some additional functions. The actual pinch function is a feeding function and in this case the pinch roll feeds the strip from its position into the mill and then the mill takes over the feeding part. But at the same time the feeding function is associated with peeling off the strip from the coiler. The coiler is, well, if the coiler would be running by itself there would not be a synchronized delivery of the strip to the mill. Furthermore, as far as I can judge, the pinch roll has a definite function of stopping the strip when the rolling process is being terminated and the mill and the coiler are being stopped. Due to the setup there is a certain danger that the strip may run over the stop position and may run out of the pinch roll and in order to avoid this the pinch roll is immediately lowered at the same time or immediately after the mill and the coiler are stopped and grips the end of the strip, trailing end of the strip and it stops that trailing end of the strip in its stopping position.

Now, the low lift position in the first place acts as a guide. This guiding function is a somewhat complex function; it limits the possibility of the strip to be raised above a certain point and thus it keeps the strip down between the side guides. It also has, under those condi-

tions, frictional contact with the strip, which helps to prevent the [569] strip of cambering or running sidewise. It also prevents the strip, which has in particular at the beginning of the rolling process a certain irregular —tendency to run irregular, and what we call to loop up, to form a sort of a loop, sort of a fold, it prevents that this fold be caught between the rolling mill and the pinch rolls and thus gives the coiler a better chance to pick up this loose material and to run up to full action. Furthermore—

Q. May I interrupt just a moment there, Doctor. In regard to the last function of preventing that looping on the exit side, if I understood your testimony, that is where the strip is coming through the mill and going to the coiler, the pinch roll in the low lift position prevents those loops from getting over to the coiler and causing irregular winding? Is that what you had in mind?

A. Well, the trouble I have seen to some extent looping is also between the rolling mill and the pinch rolls; it has a tendency to, yes, to run up into the coiler and cause poor coiling.

Q. So with that pinch roll in the low lift position that would keep the looping away from the coiling mechanism?

A. That is correct, yes.

Q. And on the other side does the pinch roll in low lift position have any effect, also, so far as that looping is concerned?

[570] A. It also helps to keep the looping down or keep the strip down. It prevents the looping from becoming dangerous.

Q. Well, does it have any tendency at all to keep the loops which might form between the coiler and the

pinch rolls away from the mill from folding over and going into the mill?

A. That is correct, that is the most dangerous effect of looping, that the strip may double up and cause difficulty.

Q. All right. Excuse my interruption, Doctor, and go ahead with your description.

A. So this is what I might call the guiding function of the low lift position. Now, the low lift position also has a certain function in tensioning the strip. It does not affect the tension as such; the tension as such is caused by the difference in speed between the mill and the coiler. What it does is, if there is some lack of synchronizing in this respect, that the pinch roll acts as a buffer and helps somewhat to equalize that tension. In addition, the pinch roll in the low lift position has a third function, and that is it keeps the strip away from the table rolls and the table aprons and thus eliminates some scratching of the strip and since, of course, this is expensive material, like stainless steel, any damage to the surface of the material is a disadvantage.

Q. Now, Doctor, I wish you would refer to the so-called modified mill and the pinch roll arrangement, the pinch roll [571] setup, and tell us what the functions are which are performed by the pinch rolls in that setup.

A. In the modified mill the pinch roll apparatus is more complicated. A third roll has been added to it and this roll has taken over the function of the low lift position so, in my opinion, this piece of apparatus by substantially the same means, performs exactly the same functions and leads to exactly the same result as the original pinch setup, which consisted of two rolls which could be lifted to a low lift position and to a high

lift position. As I said already, or mentioned already, but to make it more clear, is that now the two pinch rolls only exist in either the pinch position or the high lift position, while an additional roll is added which is lowered or raised to be in the low lift position, and both rolls together are raised to be in the high lift position.

Q. From the standpoint of the operation of the mill is there any difference between the old and the new setup?

A. There is no difference whatsoever.

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[576] Q. The claim then specifies "freeing that portion of the breakdown between the mill and the point of coiling, and tensioning such portion uniformly throughout." Will you explain the meaning of those expressions and tell us whether they apply to the Crucible modified mill, and how?

A. The freeing obviously relates to the change from the pinch position to the low lift position. Now, in the pinch position the rolls are able to provide a considerable force to the strip and thus cause the tension on one side of the pinch rolls to be considerably different from that on the other side of the pinch rolls.

[577] However, when the pinch rolls are raised to the low lift position then the strip is only very superficially in contact with both the upper pinch roll and with the deflector roll in the furnace. But this contact is not sufficient to set up any substantial difference between the tensions on one side of each roll and on the other side of each roll. So substantially there is a uniform tension under those circumstances, the same way as there is a uniform tension in a strip, or in a cord as you pull it over a pulley.

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WILLIAM H. COLVIN.

[634] WILLIAM H. COLVIN, called and sworn on behalf of the defendant, testified as follows:

The Clerk: What is your address, for the record?

The Witness: Box 2435, Route 5, Sarasota, Florida.

DIRECT EXAMINATION.

By Mr. Walker:

Q. Have you presently any connection with the defendant, Crucible Steel Company, Mr. Colvin?

A. I am a member of the board of directors.

Q. How long have you been a member of the board?

A. Since February 14, 1945.

Q. Have you at any time served the company in any other capacity?

A. On that same date I was elected president.

Q. And served as president at Crucible for how long?

A. Until May 31, 1954.

Q. Had you had any previous experience in this steel rolling business?

* * * * * * *

[635] Q. What was the situation that led Crucible to install that mill?

A. I cannot answer that too briefly, Mr. Walker. The company was—

Q. I don't want a long extended answer, Mr. Colvin. Perhaps I can ask you a more specific question and get the part of it that is really pertinent here. Was this mill installed to roll any particular type of product?

A. We had two finishing departments which this mill could be tributory to, one in agriculture implements and one in cold finished stainless steel.

[636] Q. What kind--

A. (Continuing) We thought we could expand them once we had the missing link of hot roll strip.

Q. Was hot roll strip the stocking starting material desired by the company for the production of these agricultural products?

A. Yes, sir, Crucible was well equipped to make iron and make steel, break the steel ingots down into slabs. It was not equipped to take those slabs from there into hot roll strip in coils.

Q. Hot roll strip in coils was desired for the agricultural products?

A. In coils, and in that case, in agriculture, also in straight flat material.

* * * * * * *

[639] Q. With what other type of mill were you familiar which was suitable for rolling hot steel strip coils at the time you were giving consideration to this new mill for Crucible?

A. The only other mill different from these with which I was then familiar was the Steckel type mill at McLouth Steel in Detroit, with which I was very familiar.

Q. Was that the mill that McLouth had at their Livernois Avenue plant?

A. At their Livernois Avenue plant, yes.

Q. You say you were very familiar with that?

A. Yes, I was.

Q. How did it come about that you were very familiar with that?

A. Mr. McLouth was one of my personal and most intimate friends I had in Detroit. We had a cold roll strip finishing mill at Rotary Electric for which we bought hot roll strip, such as would come off the McLouth type of mill, or a continuous mill, and we were substantial customers of McLouth Steel. He had a very great financial difficulty at the start of his career and we were interested and helpful in trying to keep him going to have a local source.

[640] Q. Were you, in view of that customer relationship you had to McLouth, in and around that Livernois mill from time to time?

A. Yes, sir.

Q. You saw it in operation?

A. Yes, sir.

Q. Now, what factors led you to choose the reversing hot mill for Crucible as distinguished from the continuous mill which you said was the other type available for producing that hot roll product?

A. Anyone who had the capacity would prefer the continuous, of course. There were two overwhelming reasons in our case, one was the fact that our total company does not produce—then or now—an amount of steel, if devoted solely to that purpose, which would supply an adequate operation on a continuous mill. A continuous mill of the width that we would need to cover the range of our products would probably have a monthly capacity substantially in excess of 150,000 finished tons a month. We can manufacture in the neighborhood of 90,000 tons in the ingots, from which something like a 70 per cent yield would come out in the finished product. And we have a substantial business in bars, rods, wire and other products, from which we did

not want to divorce ourselves and concentrate solely on strip; even if we had, we would [641] even then not been able to have used the continuous mill more than 45 per cent of its possibilities. And in that case the resulting cost relates almost directly to the rate at which you operate.

The second reason, and one which was of extreme importance, is the relative cost of the two projects. The cost of the continuous mill as of the time that I went to Crucible and had completed the study and was ready for a recommendation would be in the area of thirty-five to forty million dollars for the hot mill alone. That was wholly beyond the capacity. Our company represents between 8 and 9/10 of one percent of the steel industry. It is a specialty steel company and not a carbon volume tonnage producer.

Q. What was the approximate cost of the reversing hot mill that you did install as compared with that thirty-five to forty million dollar cost of a continuous mill?

A. The estimated cost of the installation, both hot and cold, as of the summer of 1946, before OPS went out, was twelve and a half million dollars. And I believe that what was roughly divided half and half between hot and cold, or in the neighborhood of six million for each to six and a half million for the hot mill and perhaps the same amount for the cold mill installation. We were not able to install it for that.

[642] Q. I take it from your reference to OPS that the actuality turned out to exceed the estimate?

A. Violently; yes, sir.

Q. What was the fact about that?

A. It violently exceeded it. The actual figures

were about $19 million to get what we had started out to get for $12½ million.

Q. Is there some figure that is taken as a rule of thumb as representing the cost per day of having a continuous mill set idle?

A. That figure, of course, changes with every pay raise, and every tax increase, and the cost of money, and so on. As of the time we are now talking, my recollection is that it was calculated to represent a cost of $10,000 a day not to run the mill.

Q. So I take it you didn't debate very long between the continuous mill and the reversing hot mill, once you had surveyed the field?

A. No, sir; not as between those two factors. As to what kind of a reversing hot mill, of course, we did give that all kinds of thought.

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[664] CROSS EXAMINATION.

By Mr. Webb:

Q. Mr. Colvin, where did Crucible get its hot strip prior to installing the mill, that is, the reversing hot strip mill?

A. We bought some hot strip, as such, and we supplemented that by the melting of steel and rolling slabs of our own manufacture, shipping those, I believe, to two mills, who rolled them to hot roll strip for us and shipped them back; one of which was Allegheny Ludlum, and I believe the other was Butler.

Q. And you put in the reversing type of hot strip mill that you did put in because your operation couldn't afford a continuous mill, is that correct?

A. That is one of the two reasons, yes.

Q. And Crucible couldn't afford a continuous mill?

A. Very definitely we couldn't afford it, no, sir, nowheres near.

Q. This small reversing hot mill has admirably served the purposes of Crucible since it was put in, has it not, in so far as supplying to Crucible hot roll strip for its agricultural department and for its cold rolling department?

A. It has supplied it as well as a compromise mill could, and we have not been disappointed in the mill, if that is what you mean.

* * * * * * *

[666] Q. One of the advantages of this particular type of mill for an operation such as Crucible has is its extreme flexibility in so far as rolling small orders of a wide variety of products is concerned?

A. Very definitely.

Q. And another advantage of this particular type of [667] mill is that you can provide a product that has excellent edge characteristics, is that not correct, by reason of the fact that you can keep heat in the edge portions of the strip during the rolling?

A. That is my belief. I don't want to qualify myself as one that is thoroughly familiar with that very complex problem. That is my belief, with particular reference to stainless.

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LEROY VALETTE.

[698] LEROY VALETTE, called and sworn on behalf of the defendant, testified as follows:

The Clerk: May we have your full name, please, sir?

The Witness: Leroy Valette.

The Clerk: Your address for the record?

The Witness: 12 Oak Ridge Road, Pittsburgh 29, Pennsylvania.

DIRECT EXAMINATION.

By Mr. Walker:

Q. Mr. Valette, were you at one time employed by Crucible in connection with its reversing hot strip mill?

A. Yes, sir.

* * * * * * *

[768] Q. And would the presence of those pinch rolls have any material effect, in your opinion, upon the uniformity of tension between the winding reel in the mill and between the mill and the unwinding reel?

[769] A. As against Steckel—an arrangement such as Steckel '670, I would say yes. The winding reel is supplying the force, for example, for the tension, but between the winding reel and the mill there is a pair of idler driven rolls, which are being turned by the winding reel, or the movement of the strip, due to the winding reel.

* * * * * * *

[782] Q. Do you consider it feasible to operate one of these reversing hot coiling mills without having tension on the strip, on both the delivered strip and the entering strip?

A. I can't visualize it being operated at all, from our own experience.

Q. What has your experience been in that regard?

A. That any time that there is a failure of tension on one reel or the other, as has been said by other witnesses, the material will flop from one side to the other; in other words, it will skid and do such things as that.

Q. Get into a sort of a mess?

A. That's right. In other words, the steel is coming to the winding reel faster than it can take it, so it has no set place to go to. On the unwinding reel, the same thing will apply. If it is unwinding faster than the mill is receiving it, it takes the shape somewhat of a clock spring that has been let loose.

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[788] CROSS EXAMINATION.

By Mr. Webb:

Q. Mr. Valette, you spoke this morning about the Cushwa patent. You heard Mr. Colvin's testimony yesterday, didn't you?

A. Yes.

Q. And Cushwa shows the type of mill which Mr. Colvin said Crucible could not use, does it not?

A. That is right.

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[811] Q. Now I would like to refer to some of the advantages that are specified on page 2 of the patent. Patent '065, and let's see whether or not Crucible doesn't in its modified mill get those advantages that are specified there. Montgomery states that a higher finish can be obtained than by using the 4-high mill for

both slabbing and coiling operations. That is correct, isn't it?

A. No, the finish is a function of how well you keep the finish on the rolls you are working on. What does happen, if [812] you are using two stands, you will change fewer rolls in the one stand and maintain a finish longer than you would if you were using that same mill to breakdown from four or five inches.

Q. And Crucible gains that advantage that is expressly stated there in the '065 patent, does it not, in its modified mill?

A. We divide our work.

Q. Yes. In answer to my question, it is true, isn't it, that Crucible gains that advantage that is stated there?

Mr. Walker: Just a moment. What advantage? You talked about finer finish and the witness answered you about frequency of roll changes; now, which one are you talking about?

The Court: Let's see, in the first place a higher finish can be obtained by using the 4-high mill for both slabbing and coiling operations?

Mr. Webb: "Than by."

The Court: "Than by"?

Mr. Webb: Yes, that is what it says.

Does your Honor understand that? I will develop it a little further.

(Discussion off the record.)

By Mr. Webb:

Q. It is true, isn't it, Mr. Valette, that by virtue [813] of the fact that Crucible uses the two stand in-

stallation, namely, the roughing mill and the 4-high reversing, or finishing mill, it gets a higher finish on its product than it would obtain if it did all of the operations, that is, both the slabbing and the coiling operations on the same mill?

A. As previously stated, Mr. Webb—

The Court: Well, is it true or isn't it true, or is it subject to explanation?

The Witness: Well, there is a qualification to it. It is just a question of how long you retain that finish. Now, if you do it all in one mill you will change that mill oftener to retain a given state of finish; by dividing it between two stands you will find it a little—that this set of rolls will retain that higher finish for a longer period of time. So that particular roll wouldn't be changed as often. But as far as a higher finish is concerned, the finish that you will put on it is pretty much governed by the finish that is put on in the first place and then how long it takes to become unsatisfactory.

Q. Now, this next advantage is that since the slabbing operation is confined to the Universal mill, by far the greatest portion of free scaling has occurred before the material reaches the 4-high mill, at which time it is characterized by a tight, thin layer of oxide which adheres to the strip throughout the further rolling.

[814] We have talked about that matter of free scaling so I won't need to go over that again, but I do want to ask you one question, and that is that it is true, isn't it, that the strip in the modified Crucible mill is charac-

terized by a tight thin layer of oxide which adheres to the strip throughout the further rolling?

A. Yes, we do no scaling during the rolling operation at the 4-high mill—after it has reached the 4-high mill.

Q. And the patent also states that "the output of the 4-high mill is increased from 25 to 30 per cent, furthermore, because of the fact that it is operating at high speeds a greater portion of the time than when slabbing operations are affected therein." Now as I understand that, that means that where you are doing part of the work on the one mill, doing your slabbing operations on the one millstand and doing the remainder of the work on the 4-high reversing mill, the 4-high reversing mill is able to operate at a nigher rate of speed for a greater portion of the time, and therefore the total output of the mill is increased. Is that your understanding of that?

A. Yes. It is my understanding that since another mill is doing a part of the work the work load on this mill is reduced and consequently the time for producing a finished product, rather than part of it being used for intermediate work, it does permit it to produce more, that is true.

[815] Q. Yes. And that is true with regard to Crucible's modified mill?

A. That's right.

Q. Then going down, commencing with about line 30 of that same page of the patent, the patent states: "The reduction in the wear on the rolls of the 4-high mill makes it unnecessary to change rolls as frequently as has heretofore been the case." That applies to the Crucible mill, modified mill, does it not?

A. I would like to answer it this way: that the number of roll changes in the Crucible mill—the roll changes will be more frequent per ton of output if we did all the work on one stand.

Q. All right. Then the patent mentions this matter of shearing, which you discussed, stating, "The shearing of the ends of the partly reduced slab before rolling greatly facilitates the entry of the material into the furnace reels, making the operation of the mill 15 more efficient and avoiding the delays and loss of material incident to repeated efforts to cause the end of the piece to engage the reel."

A. That is the purpose for which we shear the ends.

* * * * * * *

[830] Q. No, I realize what you said, Mr. Valette. What you, in effect, said was that there is nothing about the construction to prevent—

A. That's right.

Q. —the operator from doing this. But, of course, that doesn't advance anything at all. The fact is that Steckel teaches keeping the pinch rolls down, does he not?

A. My understanding of the patent is that he did disclose that.

* * * * * * *

[870] Q. Now referring to the Keeney & Ferm patent, which you talked about when you were discussing this '122 patent yesterday, Mr. Valette, I would like for you to tell us if it is not true that the pinch rolls in Keeney & Ferm are used only for feeding the strip to and from the mill and the coilers?

A. The pinch rolls in the Keeney & Ferm patent are used for feeding the end into the mill from the opposite side, feeding the material into the coiler, and when engaged they are disconnected from their drive and then act as idle rolls.

Q. Well, those feeding operations are the only functions performed by those pinch rolls in the Keeney & Ferm patent, is that correct?

A. Well, the Keeney & Ferm—

The Court: Well, is it correct or isn't it correct, or can't it be answered?

A. Well, as a function, yes, except that they do somewhat [871] the same thing as this roll, deflector roll here.

Q. Well, I didn't ask you about the deflector roll in the Crucible mill.

A. All right.

Q. I was asking you about the pinch rolls with Keeney & Ferm. The answer to my question is yes?

A. Yes.

Q. All right. In the Keeney & Ferm patent there is only one position for the pinch rolls, is that not correct?

A. Yes; they do not disclose raising or lowering.

Q. Yes, they stay in that one position at all times, there is no high lift or low lift position?

A. That is right.

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[896] Q. Mr. Valette, will you please turn to page 6 of patent '107, and refer particularly to Column 1, commencing at line 8. That states there, "By tensioning the portion of the breakdown between the mill and the coiling reel, I cause the material to coil tightly and

accurately on the coiling reel, thus avoiding skidding and possible deformation of the edge of the breakdown on the next pass."

That is done and that advantage realized in the Crucible modified mill, is that correct?

A. Yes, we tension it between the mill and the breakdown.

Q. And the answer to my question is yes?

A. Yes.

Q. The specification then proceeds, "The tension also serves to remove any camber which might be rolled into the strip by the mill."

The tension on your Crucible modified mill functions in that way, does it not?

A. Can I make a slight reservation, in that tension will sometimes remove camber and sometimes won't, depending on the thickness and various other factors.

[897] Q. Generally speaking, however, where tension would be capable of removing the camber in the Crucible modified mill, the tension which is employed serves that purpose?

A. Yes.

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DR. GEORGE SACHS.

DIRECT EXAMINATION.

By Mr. Webb:

[933] Q. Did you on your visits to the Crucible hot strip mill during 1955 observe the so-called hold-down or auxiliary roll in operation?

A. Yes.

Q. What were your observations as to the operation of that roll and the conclusions you drew?

A. I noticed that the hold-down roll was going up and down by somewhere between a half inch and one inch—this of course is a guess—repeatedly during the operation of the mill.

Q. What conclusion did you draw, Doctor?

A. From this observation I drew the conclusion that the hold-down roll assisted in tensioning the strip. Now, in order to explain how I arrived at my conclusion I would [934] like to mention, or I would like to say that when a strip is under tension as it runs over a roll with a certain angle, it exerts a considerable force on that roll. Now, if that roll is backed up elastically, as it is in the case of either hydraulic or pneumatic pressure, then the tension of the strip—variations in the tension of the strip will reflect themselves in movements, up and down movements, of that roll. Certain variations, not all variations will reflect. At the same time, if the roll goes say up, it means that the tension in the strip has a tendency to increase. However, if the roll goes up, the pass of the strip becomes shorter and this in turn reduces, again, the tension, so there is a certain counterplay between the hold-down roll and the tension in the strip. This play is in that respect that the roll helps to keep the tension in the strip more uniformly than it would if that roll would be rigid or wasn't there at all.

* * * * * * *

[940] Q. Now, doctor, do you have the Montgomery '107 patent there before you?

A. Yes.

Q. Referring to the structure disclosed, and the operation described in patent '107, in regard to the tensioning of the strip, would you please tell us whether the apparatus and the method described there neces-

sarily provide uniform tension between the mill and the points of coiling?

A. Yes, as far as I can understand this claim, freeing of the portion of the breakdown between the mill and the point of coiling necessarily provides tensioning of this portion of the strip uniformly throughout.

Q. Now, that is not exactly what I had in mind, doctor. In the patent there is a description of the tensioning of the strip, and there is the apparatus that is disclosed in the drawing, and my question is merely [941] whether, if you utilize the apparatus and follow the teaching of the patent in regard to tension, do you necessarily obtain the uniform tension between the point of coiling and the mill?

A. Yes, I do.

Q. Now, doctor, at pages 767 and 768 of the record Mr. Valette testified about the tension apparatus and the so-called tension disclosure of the Keeney & Ferm patent. Now, I wonder if you will tell us what the correct situation is regarding tension on the strip, on the winding or exit side of the Keeney & Ferm mill?

A. The apparatus disclosed in the Keeney & Ferm patent has not the ability to retain or to keep the tension constant if there is no synchronization between the mill and the coiler. The only function which this apparatus has is to take up the loop and to prevent the loop of folding over on itself. But it has no effect on synchronizing and therefore no effect on the tension.

It can be also shown—I could demonstrate it, if necessary—that once the tension is relieved, once—the tension which is being set up by this looping arrangement is insignificant compared to the tension which is necessary to hold that looping arrangement down in its

normal position where it is practically flat, where the rolls are all in one line.

[942] Q. So that your conclusion is what, as regards the tension on the strip in that Keeney & Ferm patent?

A. That device is completely inoperative as far as maintaining tension in the strip is concerned, and only operative as far as keeping the loop under control or out of the way where it could do some damage.

Q. Now, Doctor, does that Keeney & Ferm patent disclose any structure providing for uniform tension on the exit side?

A. I have to look up that patent again.

Q. Well, I think you may have already answered what I have in mind in that particular question, Doctor. I was just more or less summarizing what you had previously said on that subject. Let me modify my question to state it in this way: As I understand what you have stated, the patent does not disclose a structure on the exit side for providing uniform tension in the strip, is that right?

A. That is correct, yes, with the emphasis on uniform.

Q. Yes. Now, in that same Keeney & Ferm patent you find a band brake for the avowed purpose of putting tension on the strip as it goes into the mill. What can you say as to the effectiveness of a band brake such as that disclosed in the Keeney & Ferm patent for putting tension on the strip?

A. Well, the band brake is a poor means of applying tension; [943] primarily for two reasons: the one is that today band brakes are known to be very inconsistent and they don't last very long, and during the life of the brake the tension changes considerably—changes con-

siderably. In addition, a band brake is a means of applying a constant torque, or intended to apply a constant torque on a coiler. However, as the coil keeps on growing when the strip is wrapped around the coil, in order to get a uniform tension in the strip the torque would have to increase in proportion to the diameter of the coil, and the band brake, of course, cannot be adjusted or cannot allow to provide or to supply this necessary increase in torque with increase in the diameter of the coil.

Q. You spoke, Doctor, about the increase in the coil size. We are talking about the entry side of the mill. Does that same situation prevail in the reverse, where the coil side is going down?

A. Yes; I made a mistake, I should have said the coil is decreasing in size and the torque has to decrease to provide a constant or uniform tension, and the band brake is not in a position to provide this function.

Q. Now, Doctor, will you please tell us the relationship between the speed of the strip as it leaves a pair of reducing rolls and the speed of the rolls themselves, and if you care in your explanation, you may bring in the [944] entering speed of the strip so as to complete the picture. But I am particularly interested in the relationship between the speed of the strip as it goes out of the mill and the speed of the reducing rolls.

A. Well, I assume it is quite clear that the speed of the strip on the entry side is much less than on the exit side.

Q. Well, is that necessarily so when you are reducing metal?

A. That is necessarily so because I have to pass the same volume through in front as I have in back, and

as the strip is thinner in front than in back it has to run faster to make up the same volume in the unit of time. Now, that means automatically that the roll, the speed of the surface roll has to be somewhere between those two speeds because otherwise it would not supply or feed, as we say, the strip through the mill. So the speed of the roll is between the exit speed and the entry speed. Now, what is actually the surprising and somewhat difficult point to explain is that it is much closer to the exit speed than to the entry speed. Offhand, one would imagine that it would be halfway between the two speeds, but there are two reasons for that, which I may explain in using Exhibit No. D-1-A.

Q. Fig. 1.

A. I am showing, or I am pointing to the curved contact [945] surface, the curved line just over the lower roll, just above the lower roll. This is the contact surface, or line in this case, between the strip and the roll. Now, if I had a pressure about halfway on that curved line acting on the roll, which we call the resultant pressure, this would be the point where the strip and the roll run at the same speed. And left of this line the strip would run faster and right of this line the strip would run slower. In other words, what happens is that roll pushes the strip together, it squeezes metal out, back and forth, and these are superimposed to the uniform movement of the strip.

Now, you can see, or one can see that the thickness of the strip at this halfway point is on a curved line much closer to the thickness in front than to the thickness in back. In fact, what that means, if you would assume that the pressure was halfway on that contact area, that the difference in speed between front and roll

would be about a quarter or a third of the difference in speed in back. So say we have a reduction of the 25 per cent, then the strip would run in front maybe five or six per cent faster than the roll, and in back of the roll 17, 18 per cent slower than the roll.

Now, actually what we call the no slip point, the point where the roll and the strip run at the same speed [946] is actually, usually, much closer to the front, to the exit of the strip than to the back. That accounts for the fact that then the strip at the exit runs only a few per cent instead of six per cent, say only two or three per cent faster than the roll.

Q. And is that the order of magnitude of that difference in speed, Doctor?

A. Well, as I say, under normal condition it may be two or three per cent, or may be even less; under certain abnormal conditions it may be as much as 10 or 15 per cent faster than the roll.

Q. Now, Doctor, at pages 777 to about 779 of the record Mr. Valette testified regarding preventing looping, and he testified that the pinch rolls do not have any effect on preventing looping. Would you please tell us what the situation is in regard to the pinch roll in its low lift position in the Crucible mill and in regard to the auxiliary or hold-down roll in the Crucible mill so far as preventing looping from forming, or whether they have any effect at all in the event that loops do form as a result of some condition in the mill?

A. Well, neither the pinch roll in the low lift position nor the hold-down roll in the lower position prevents looping. As I expressed before, the looping is simply and singly the function of the relative speeds of roll, [947] coiler and uncoiler. However, if there is some looping

then the pinch roll in the low lift position and the hold-down roll in its lower position, have a certain function, and that is that they can keep the loop away from the mill and, therefore, avoid that any loop will fold over and be rolled over by the mill. In other words, they exert a certain control about the position of the loop, and in that respect avoid serious damage due to looping. They won't eliminate it. If the looping is bad there is nothing which can help it.

Q. In other words, the pinch roll in low lift position and the auxiliary roll in low lift position do not prevent the looping, but they do prevent the loops which do form from interfering with the proper operation of the mill?

A. That is correct.

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RALPH A. FREED.

DIRECT EXAMINATION.

By Mr. Webb:

[969] Q. Where did you first install pinch rolls with the high lift-low lift position?

A. Well, I have testified to that before, but it was either [970] the Dominion mill or the McLouth mill, because they were both going through practically at the same time.

Q. Well, did the installation of those pinch rolls accomplish what Mr. Montgomery had in mind, as you described it?

A. Yes, it certainly assisted in helping us from damaging that equipment. We had no further trouble from that end, but we also, as I have testified before, to our great surprise, we had a lot of other functions come

up that assisted us in our operation of that mill that made it really possible. I have gone into that before so I don't think it is necessary to enumerate those all again.

Q. You say you were surprised, is that the word you used?

A. Yes, because we hadn't anticipated those things.

Q. You are referring to the functions which you described in your testimony earlier?

A. That is right.

Q. Yes. Did those functions materially assist in solving any problems relating to the feeding of the strip?

A. A lot of the difficulties that we had previous to that time were more or less eliminated or decreased in effect.

* * * * * * *

[971] Q. Are you familiar with band brakes of the character described in the Keeney & Ferm patent for braking the unwinding reel?

A. I am, yes.

Q. What has been your experience to the effectiveness of such a brake that provides uniform tension on the strip?

A. Well, primarily the usage of a band brake, in most all instances, is to stop a rotating body. If something is rolling, your brake is here, it clamps onto it and stops it. But as far as any type of brake of that kind to maintain a constant tension throughout its life, or a long period of time, you run into this difficulty: You have generally a metal disk and friction material called the brake band that come together. This brake band is of such a nature that it will, under high speed and

usage, will have a tendency to glaze over, just like your old brake bands used to in automobiles, so after they got so old they would slide and wouldn't hold. Well, you had that effect and therefore when it would slide your tension would be entirely different. And another thing, it wears, it gets down thinner and you have to replace your band occasionally. All right, it would require constant adjustment to take advantage of that wear. So those two [972] things would make it practically impractical from an operating standpoint to be able to have that type of a brake that would maintain any constant tension over any period of time.

Q. Would such a brake operate in such a way as to compensate for change in the diameter of the coil of strip as it is being unwound?

A. No, I think Dr. Sachs covered that, that it doesn't take into any effect of the various size of the coil, either increasing or decreasing.

Q. Does that have an effect on uniformity of tension?

A. It would, because you have your torque arm that you are operating through.

* * * * * * *

Plaintiff's Exhibit P-2.

Plaintiff's Exhibits.

EXHIBIT P-2—Agreement Between Cold Metal and Crucible, Dated September 30, 1946.

AGREEMENT

THIS AGREEMENT made the 30th day of September, 1946, by and between THE COLD METAL PRODUCTS COMPANY, a corporation of Ohio, having a place of business at Youngstown, Ohio, (hereinafter referred to as "COLD METAL"), party of the first part, and CRUCIBLE STEEL COMPANY OF AMERICA, a corporation of New Jersey, having a place of business at New York, New York, (hereinafter refererd to as "CRUCIBLE"), party of the second part,

WITNESSETH:

WHEREAS:

A. COLD METAL warrants and represents that it is the owner of the following United States Letters Patent:

Patent Nos.:	1,857,670	2,087,065
	1,918,968	2,116,121
	1,977,214	2,214,107
	2,072,121	2,219,150
	2,072,122	

and that it has the right to grant thereunder the license herein set forth.

These patents and any patents covering improvements thereon which COLD METAL may now own or may hereafter own or acquire are hereinafter collectively referred to as the "Cold Metal patents."

Plaintiff's Exhibit P-2.

B. CRUCIBLE desires to acquire and COLD METAL desires to grant the hereinafter defined licenses under said Cold Metal patents.

NOW, THEREFORE, in consideration of the mutual promises hereinafter set forth, each party executing this agreement with the intention of being legally bound hereby, it is agreed as follows:

SECTION I

1.

The term "simple steel" as used herein means steel in which carbon is the only element employed to control physical properties, although such steel may contain some manganese (less than 1%) with a minimum of impurities including residuals (less than 1% in aggregate). "Low carbon steel," for the purposes of this agreement, is a simple steel having a carbon content of .25% or under. "High carbon steel," for the purposes of this agreement, is a simple steel having a carbon content of more than .25%.

2.

The term "alloy steel" as used herein means a steel which, in addition to carbon, contains another element or elements in sufficient amounts to modify the properties to a marked degree from simple steel. It includes those products generally known in the trade as "stainless steel" and "silicon steel."

3.

"Products" or "steel" as used in this agreement shall be only products or steel rolled on mills owned or operated by CRUCIBLE coming under the Cold Metal

patents, and in the rolling of which one or more of the inventions covered by the Cold Metal patents are utilized.

SECTION II

COLD METAL hereby grants to CRUCIBLE a nonexclusive right and license under said Cold Metal patents (a) to make or have made for its own use mills and equipment coming under the Cold Metal patents, (b) to own and use said mills and equipment, (c) to practice processes coming within the scope of the Cold Metal patents throughout the United States, its territories and possessions, and (d) to use and sell the products of said mills, equipment and processes anywhere in the world.

SECTION III

CRUCIBLE shall pay or cause to be paid to COLD METAL royalties as follows:

1.

For low carbon simple steel rolled on mills or equipment under said Cold Metal patents, according to the following Schedule "A":

	Thickness	Royalty per ton of 2000 pounds
SCHEDULE "A"	.250" and heavier	25¢
	.125" to .249"	50¢
	.060" to .124"	75¢
	Thinner than .060"	$1.00

2.

For high carbon steel rolled on mills or equipment under said Cold Metal patents, $2.00 per ton, irrespective of thickness.

3.

For all other products, including alloy steels, rolled on mills and equipment under the Cold Metal patents,

2½% of the selling price. The selling price shall be determined in the manner set forth in Paragraph 4 hereof.

4.

In respect of all products rolled on the licensed mills and equipment, and sold by CRUCIBLE in the hot rolled condition, in coil or sheet form, the term "selling price" as used herein shall mean the selling price actually charged by CRUCIBLE to the purchaser. As to products rolled on the licensed mills and equipment and either subsequently cold rolled or fabricated into articles by CRUCIBLE from the hot rolled products, the term "selling price" as used herein shall mean the price at which CRUCIBLE is currently selling the particular grade of material, hot rolled in coils or sheets, whichever is lower. If, however, CRUCIBLE is not currently selling such material in the hot rolled condition as aforesaid, then the term "selilng price" as used herein shall mean the prevailing regular market price of such material, hot rolled in coils or sheets, whichever is lower. In the further event, however, that CRUCIBLE is not selling such material hot rolled as aforesaid, and if there is no prevailing regular market price for such material, then, in that event, the term "selling price" as used herein shall maen CRUCIBLE'S cost of said hot rolled product plus 15% thereof, as certified to COLD METAL BY CRUCIBLE supported by the affidavit of CRUCIBLE'S comptroller. In determining said "selling price" none of the following extras charged to the purchaser shall be included:

Cutting to length
Forming
Slitting
Circle cutting or blanking

Plaintiff's Exhibit P-2.

Leveling
Commercial testing
Perforating
Packing
Tolerance for width
Trimming for width
Annealing
Straightening
Pickling
Oiling or Liming

5.

Royalty payments shall be made monthly and shall be due on the twentieth day of each month covering salable production of the previous calendar month. Salable production is defined as all material which is shipped or used. In the case of material being rejected by a customer of CRUCIBLE or by CRUCIBLE and later used by CRUCIBLE as scrap or sold as scrap at scrap prices, no royalty shall be payable to COLD METAL on such material. Each royalty payment shall be accompanied by a statement showing the entire production of royalty-bearing material by CRUCIBLE during the previous month. Each monthly statement shall include a complete report of all rejected material and the disposition made of such material.

6.

CRUCIBLE shall keep or cause to be kept accurate books of account showing the amount of royalty determined under subparagraphs 1, 2 and 3 above, and CRUCIBLE'S books and records relative to actual sales, to its current selling prices, and to the production of products shall be open to the inspection of representatives

of COLD METAL acceptable to CRUCIBLE at any time during reasonable business hours.

7.

It is understood that CRUCIBLE at the present time does not own or operate mills or equipment under said Cold Metal patents, that nevertheless it is presently contemplating the installation of such mills and equipment, but that the installation of such mills and equipment may not be completed for a period of more than one year from the date hereof. Consequently, the royalty rates set forth above in this Section III are the royalties which will become applicable only upon the installation and commercial operation of the licensed mills and equipment, and shall not be considered as effective for any purpose whatsoever until the date when such commercial rolling of steel on the licensed mills and equipment is commenced by CRUCIBLE.

8.

The royalties specified herein shall continue at the full rates set forth in this Section III until the expiration of patent No. 1,977,214 on October 16, 1951. Thereafter, throughout the remaining life of the licenses granted hereby, the royalties payable shall be at the rate of fifty per cent (50%) of the royalty rates specified above. It is understood and agreed, however, that the royalty payments specified herein are to continue only so long as CRUCIBLE'S mills and equipment or operations are covered by unexpired claims of the Cold Metal patents, and this irrespective of the duration of this agreement.

SECTION IV

If COLD METAL shall acquire any further patents within the life of this agreement covering improve-

ments upon the inventions of the patents set forth in Paragraph A hereof, such improvement patents shall be included in this agreement to the same extent as if specificallly listed in Paragraph A hereof, and CRUCIBLE shall be licensed under such improvement patents to the same extent as under the patents specifically listed above in Paragraph A.

SECTION V

In the event that COLD METAL, at any time hereafter, shall grant to another licensee in the United States, its territories or possessions, for the subsequent manufacture of the same materials herein contemplated on reversing hot mills or equipment falling within the scope of one or more of the patents set forth above in Paragraph A, or should amend any existing license agreement so as to grant, more favorable royalty rates than the rates specified in Section III, sub-paragraphs 1, 2 and 3 hereof, the royalty rates for this license shall at the same time be reduced to such more favorable rates for the remaining life of this license. COLD METAL shall promptly disclose to CRUCIBLE the fact of the granting of any more favorable rates than those herein specified.

COLD METAL warrants and represents that, except for licenses hitherto granted by it or by The Cold Metal Process Company (its predecessor in title) to Youngstown Sheet and Tube Company and Dominion Foundries and Steel Limited, neither it nor its said predecessor in title has hitherto granted any license under the Cold Metal patents, or any of them, which provide for royalty rates which are more favorable to the licensee than those herein above specified. Any reduction granted or

ordered by The District Court of the United States for the Eastern District of Michigan, in a suit pending in that Court brought by The Cold Metal Process Company against McLouth Steel Corporation, at Civil 1686, in the royalty rates specified in a license granted by COLD METAL or its predecessor in title to said McLouth Steel Corporation shall not be deemed a grant by COLD METAL of a more favorable license within the meaning of this Section V.

SECTION VI

Unless sooner terminated as hereinafter provided, this agreement shall continue in full force and effect throughout the life of each of said Cold Metal patents which is of such character and scope as to cover the mills or equipment installed or to be installed by CRUCIBLE, or the operation thereof, and shall continue throughout the life of each improvement patent which COLD METAL may hereafter acquire and under which a license is hereby granted to CRUCIBLE.

SECTION VII

If, during the duration of the licenses hereby granted, any claim or claims of any of the Cold Metal patents shall be held invalid or limited by a court from whose decision no appeal is taken or no appeal or other proceeding for review can be taken, then for the purpose of this agreement, said claim or claims shall be considered as if they had expired or as limited by said decision as of the date of the final decree or affirmance of the holding of said court, and royalties payable after the date of said decree or the affirmance of the holding of said court shall be paid only for products rolled on mills coming within the scope of unexpired claims of said patents as limited by said decision.

Plaintiff's Exhibit P-2.

SECTION VIII

COLD METAL shall in good faith endeavor to enforce and maintain valid all of said COLD METAL patents. In case the parties hereto cannot agree as to the steps which COLD METAL should take against an alleged infringer, and COLD METAL does not, in good faith, believe that the bringing of suit is reasonably required for the protection of CRUCIBLE under the licenses herein granted, then the matter shall be submitted to three arbitrators whose judgment shall be final and binding upon the parties hereto. If the arbitrators' decision is in favor of CRUCIBLE, then COLD METAL shall sue such alleged infringer and thereafter diligently prosecute the same to a final adjudication or until said infringement is effectively terminated, but if the decision is in COLD METAL'S favor, then there shall be no obligation to bring suit under the circumstances existing and presented to the arbitrators. COLD METAL shall have a reasonable time to bring suit (not to exceed thirty days) from the date of the decision by the arbitrators in CRUCIBLE'S favor. In case it does not bring suit within such time or does not thereafter diligently prosecute the same as aforesaid, CRUCIBLE shall be relieved of the obligation to pay royalties under Section III, subparagraphs 1, 2, and 3 hereof from the date of the arbitrators' decision up to the date when suit is brought against such alleged infringer and also during any period within which COLD METAL fails diligently to prosecute said suit as aforesaid.

The arbitrators shall be selected in accordance with the provisions of the laws of Pennsylvania governing both original appointment and the filling of vacancies in force at the time the arbitration is invoked. Regard-

less of the place where the dispute arises, arbitration shall be held in Allegheny County, Pennsylvania.

In no event shall COLD METAL be required to litigate its patents against more than one alleged infringer at a time.

SECTION IX

COLD METAL agrees to hold CRUCIBLE harmless, up to the amount of royalties paid to COLD METAL by CRUCIBLE, in the event that suit is brought against CRUCIBLE charging infringement by it of any existing unexpired patent by reason of the use of methods or apparatus indispensible to the use of the inventions covered by the Cold Metal patents under which CRUCIBLE is licensed hereby; provided, however, that CRUCIBLE must notify COLD METAL of the institution of any such suit within ten (10) days after the institution thereof and give COLD METAL the opportunity to come in and defend the same.

SECTION X

The licenses hereby granted are personal to CRUCIBLE and shall not be assigned except as a part of and in conjunction with the sale or assignment of the entire business of CRUCIBLE or the merger or consolidation of CRUCIBLE into or with another company, or the sale or assignment of all that portion of the business of CRUCIBLE in which the licensed mills and equipment are employed. In the event of any such assignment, the terms of the licenses granted hereby shall be binding upon such assignee.

This license shall be assignable by COLD METAL. In case of any such assignment by COLD METAL it shall re-

Plaintiff's Exhibit P-2.

quire the assignee to assume all its obligations hereunder.

SECTION XI

At any time after March 1, 1953, CRUCIBLE shall have the right to cancel this agreement upon giving COLD METAL thirty (30) days advance notice in writing of its intention to cancel.

IN WITNESS WHEREOF, the parties hereto have executed this agreement as of the day and year first above written.

THE COLD METAL PRODUCTS COMPANY

By /s/ W. B. LOCKWOOD
President

Attest:
/s/ W. H. KILCAWLEY

CRUCIBLE STEEL COMPANY OF AMERICA

By /s/ W. H. COLVIN, JR.

Attest:
/s/ K. R. VOGEL

Plaintiff's Exhibit P-3.

March 2, 1937. A. B. MONTGOMERY 2,072,122

ROLLING MILL

Filed Dec. 4, 1934 6 Sheets-Sheet 1

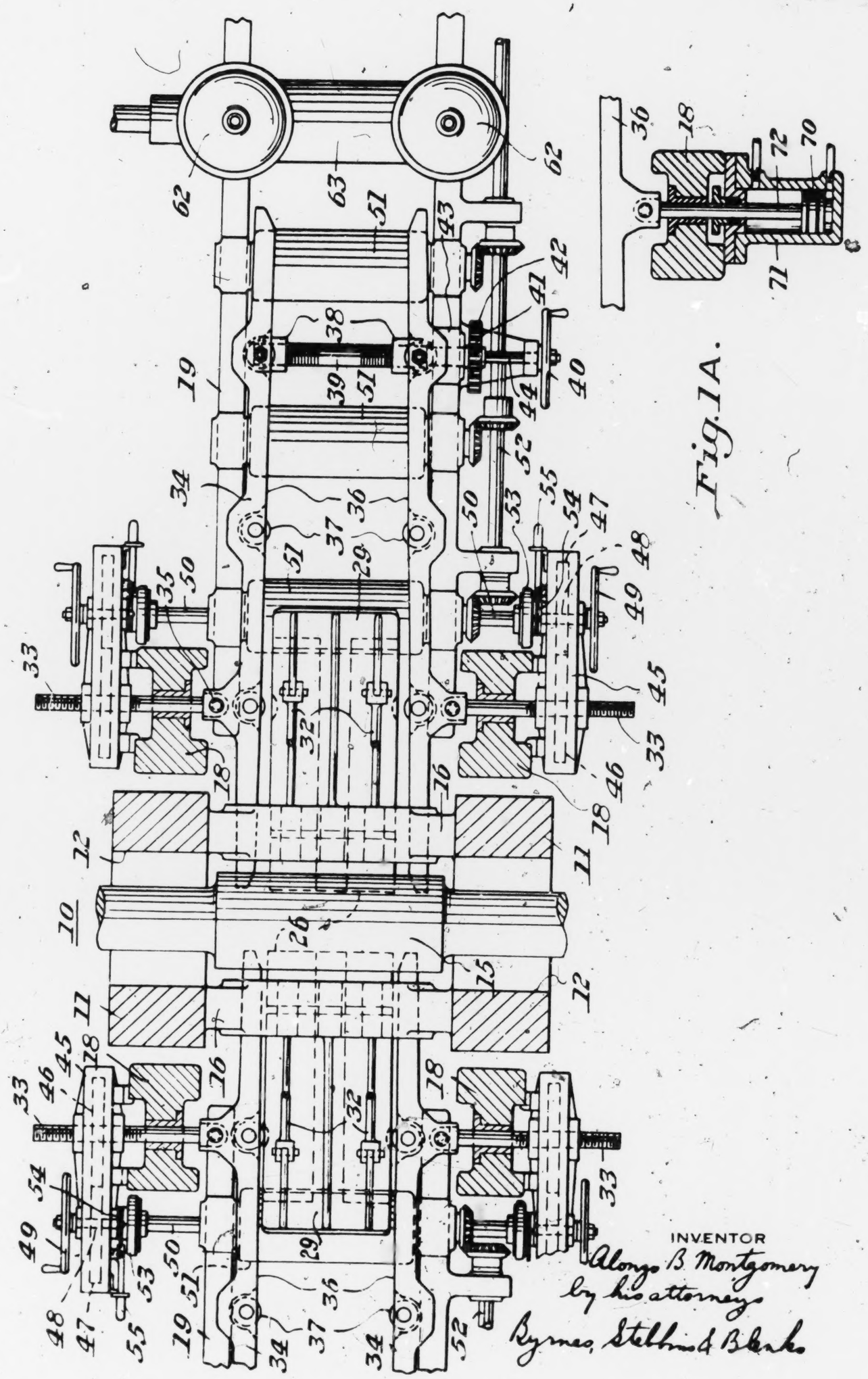


Fig. 1.

Fig. 1A.

INVENTOR
Alonzo B. Montgomery
by his attorneys
Byrnes, Stellman & Black

March 2, 1937. A. B. MONTGOMERY 2,072,122

ROLLING MILL

Filed Dec. 4, 1934 6 Sheets-Sheet 2

Fig. 3.

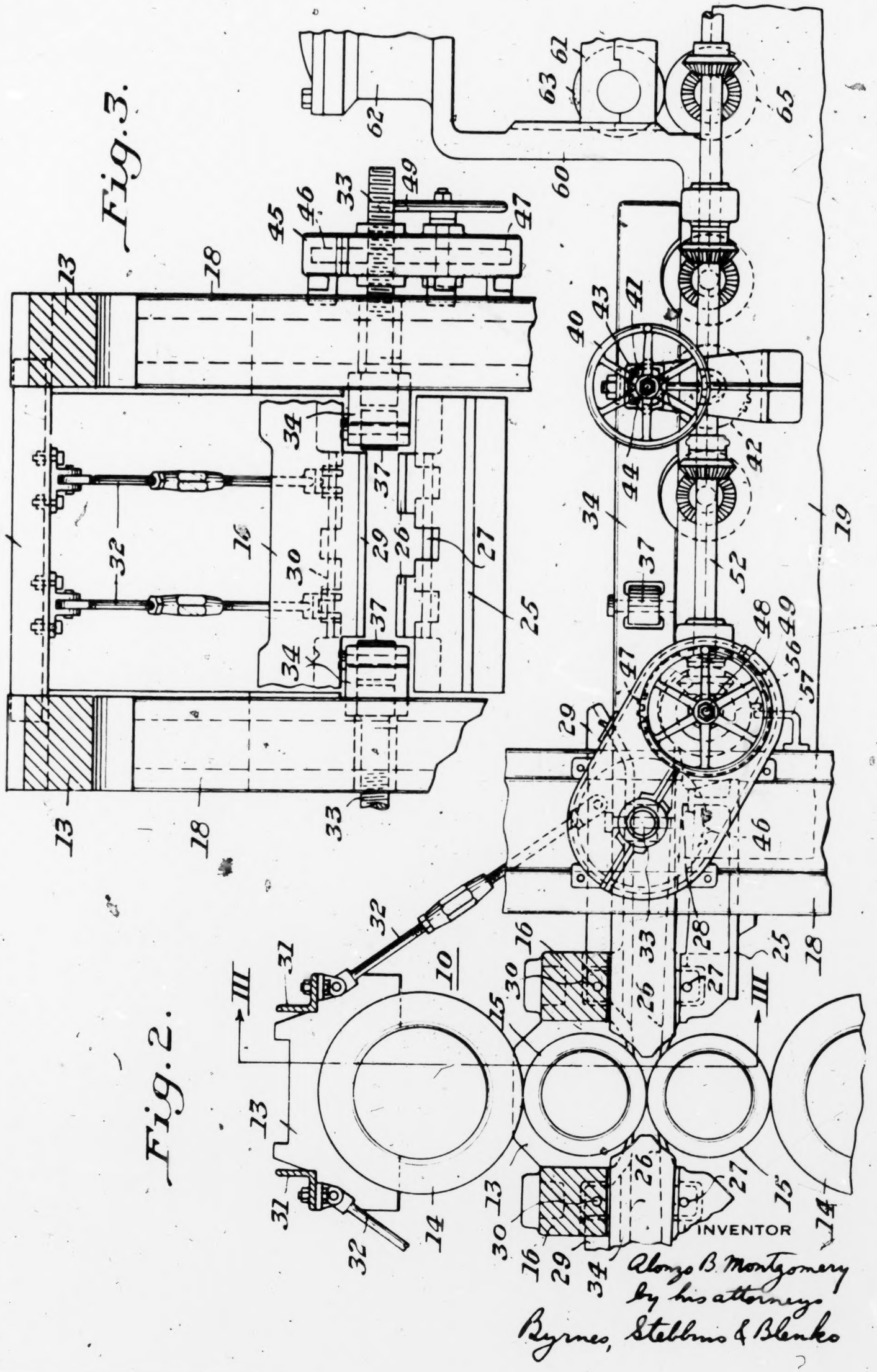


Fig. 2.

INVENTOR

Alonzo B. Montgomery

by his attorneys

Byrnes, Stebbins & Blenko

March 2, 1937. A. B. MONTGOMERY 2,072,122

ROLLING MILL

Filed Dec. 4, 1934 6 Sheets-Sheet 3

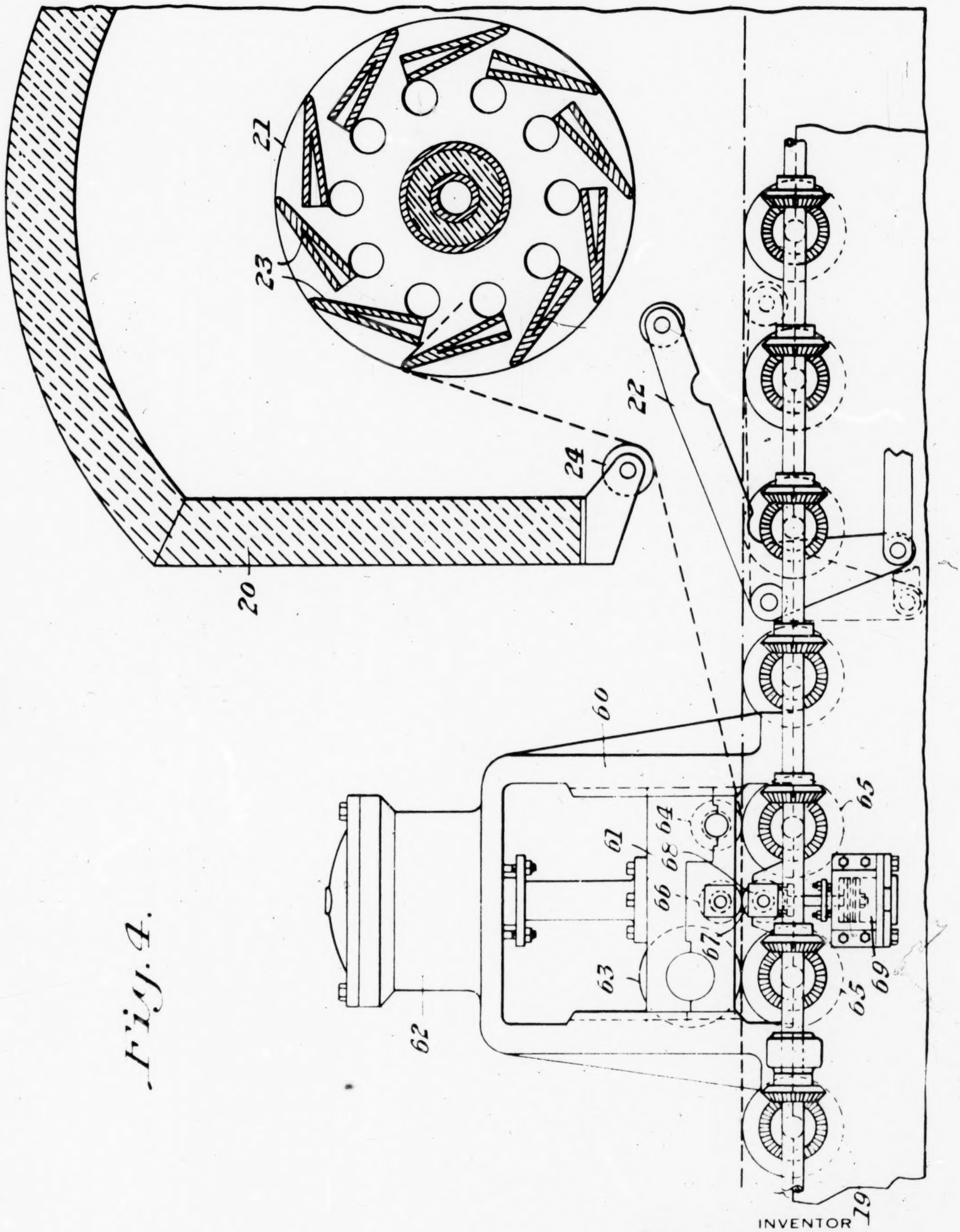


Fig. 4.

INVENTOR
Alonzo B Montgomery
by his attorneys
Byrnes, Stebbins & Blenko

March 2, 1937. A. B. MONTGOMERY 2,072,122

ROLLING MILL

Filed Dec. 4, 1934 6 Sheets-Sheet 4

Fig. 7.

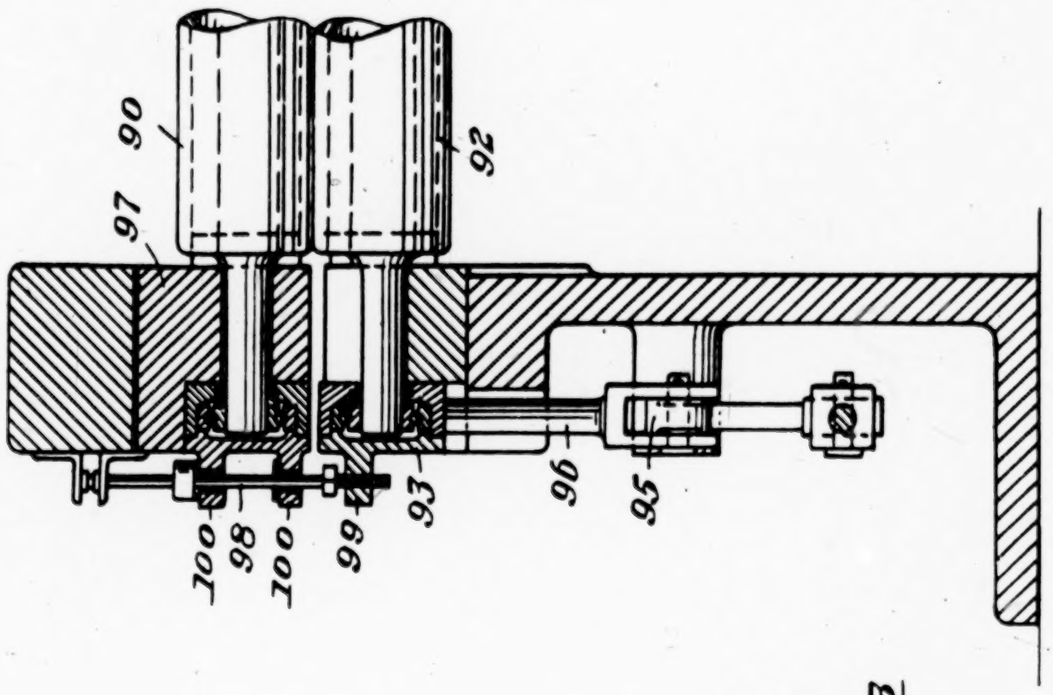
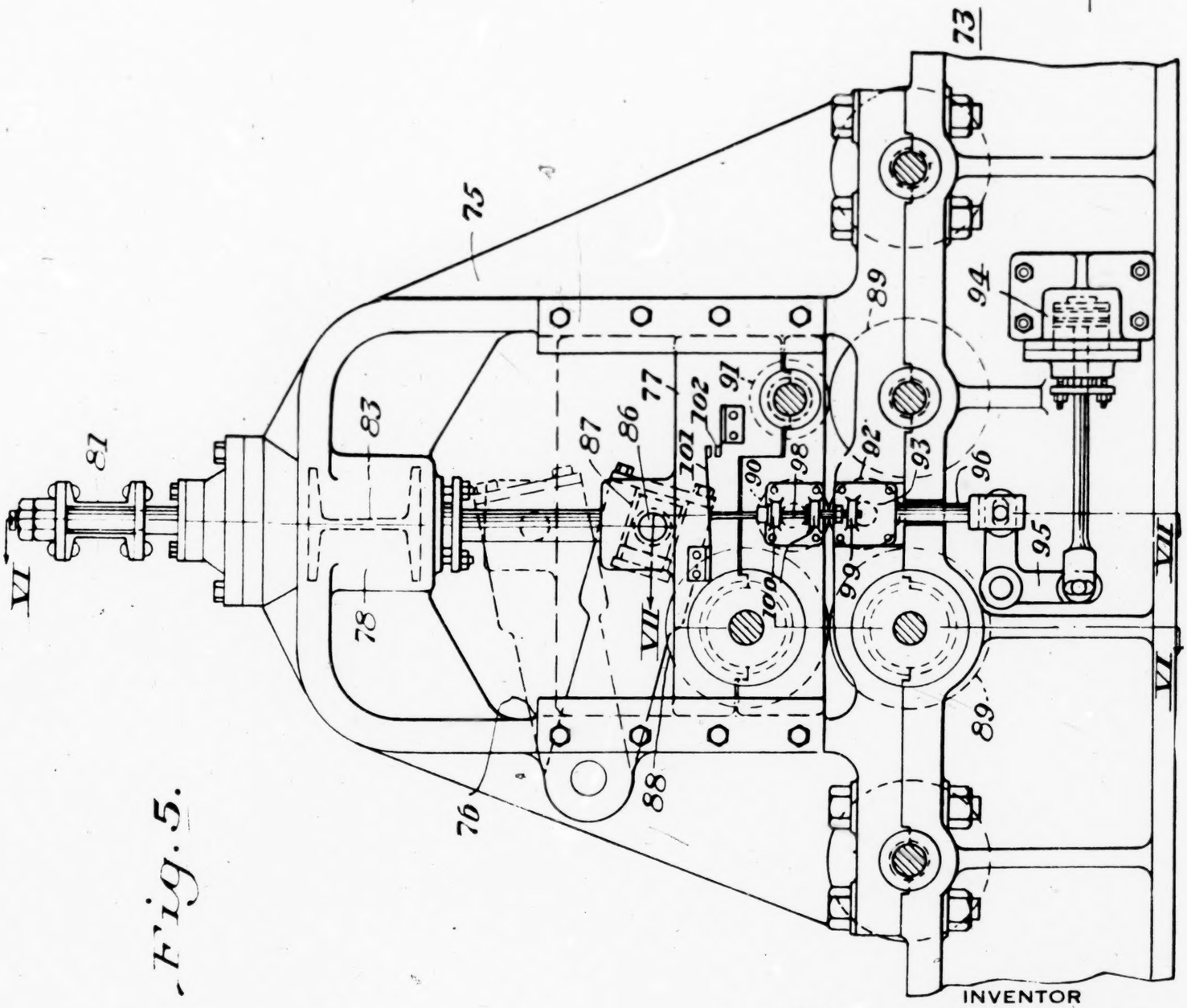


Fig. 5.



INVENTOR

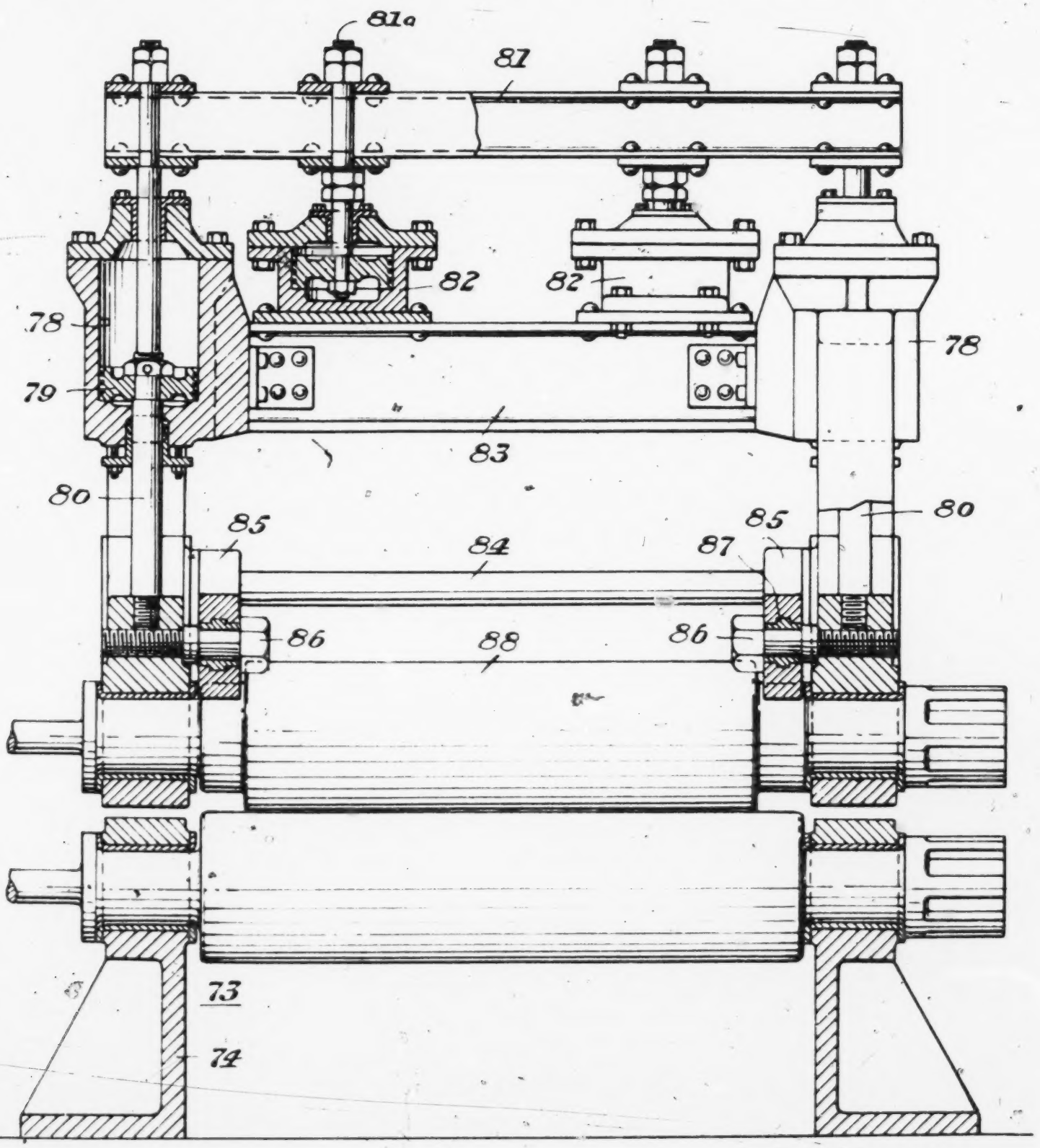
Alonzo B. Montgomery
by his attorneys
Byrnes, Stebbins & Blenko

March 2, 1937. A. B. MONTGOMERY 2,072.122

ROLLING MILL

Filed Dec. 4, 1934 6 Sheets-Sheet 5

Fig. 6.



INVENTOR

Alonzo B. Montgomery

by his attorneys

Byrnes, Stebbins & Blanko

March 2, 1937. A. B. MONTGOMERY 2,072,122

ROLLING MILL

Filed Dec. 4, 1934 6 Sheets-Sheet 6

Fig. 8.

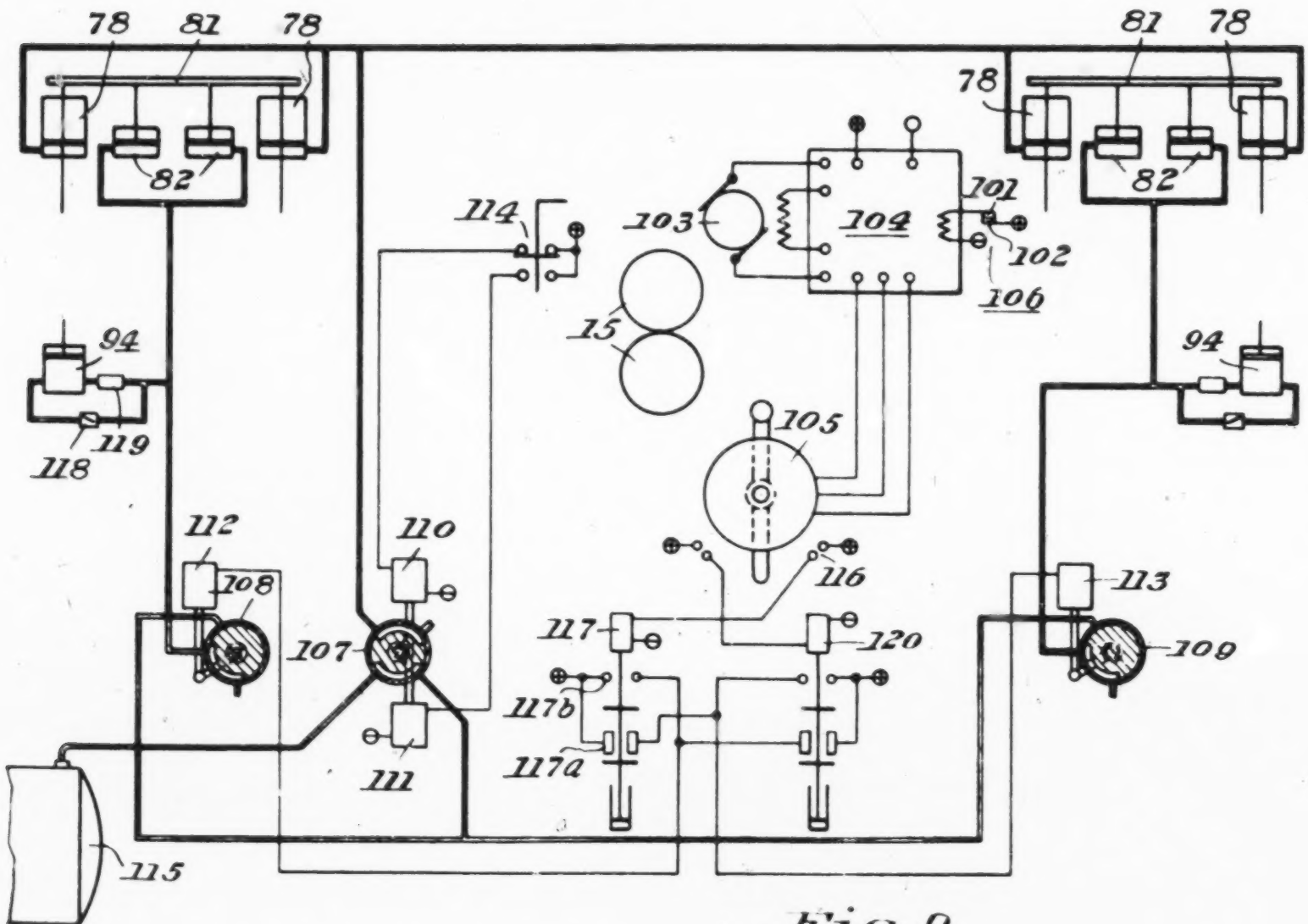
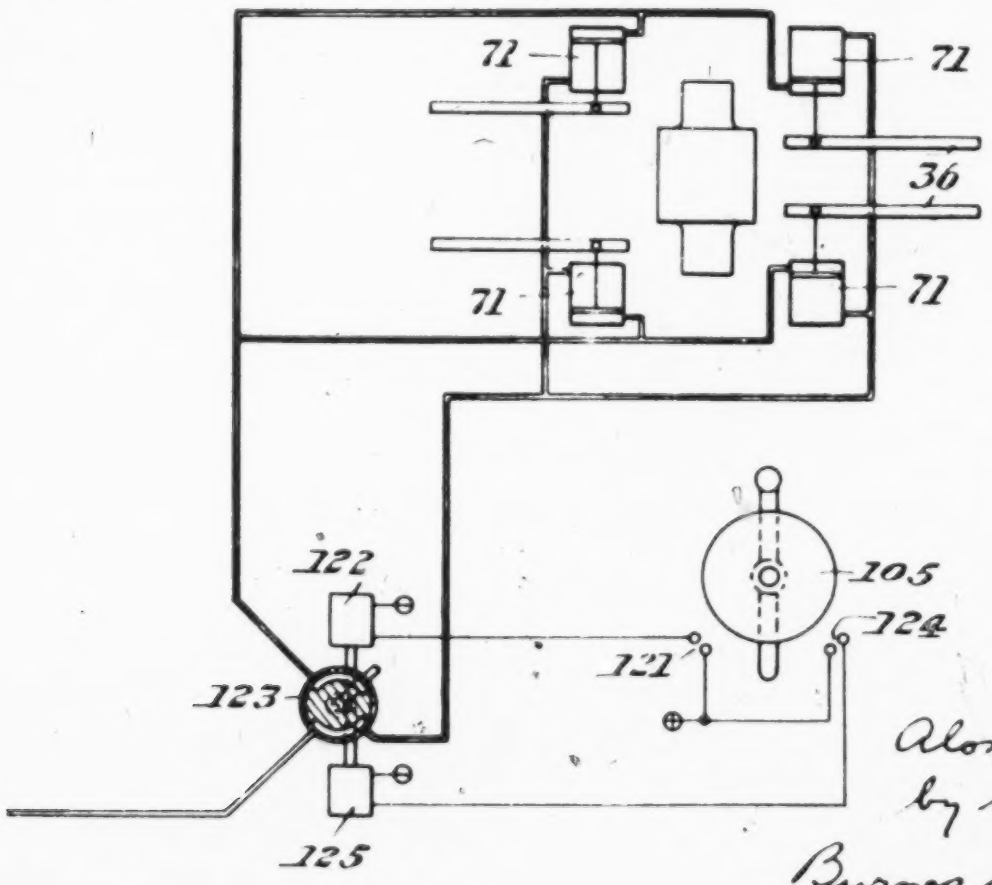


Fig. 9.



INVENTOR

Alonzo B. Montgomery

by his attorneys

Byrnes, Stebbins & Blenko

Patented Mar. 2, 1937 2,072,122

UNITED STATES PATENT OFFICE

2,072,122

ROLLING MILL

Alonzo B. Montgomery, Youngstown, Ohio, assignor to The Cold Metal Process Company, Youngstown, Ohio, a corporation of Ohio

Application December 4, 1934, Serial No. 755,886

20 Claims (Cl. 80—32)

My invention relates to the rolling of metal and, particularly, to the hot rolling of strip and a mill therefor.

In the patents to Keeney et al. No. 1,918,968, and Steckel No. 1,977,214, there are disclosed four-high reversing mills with coiling furnaces on opposite sides thereof for hot rolling strip. My invention is concerned generally with improvements in mills of this type.

Commercial use of mills of the Keeney and Steckel type has disclosed the fact that it is sometimes difficult to cause the material being rolled to enter the rolls properly, namely, at precisely right angles to the plane containing the roll axes. The hot strip, being of comparatively small thickness in the later stages of rolling, has little or no rigidity and it has been found that the strip or the slab from which it is rolled, may become cambered or elongated more along one diagonal than the other if great care is not exercised in directing the piece properly into the mill.

Further difficulty has been experienced in causing the leading end of the material properly to engage the coilers within the furnaces on opposite sides of the mill. It frequently happens that the leading end of the piece becomes bent at a slight angle to the main body thereof and this condition, if not corrected, makes it difficult or impossible to cause the material properly to engage the coiler.

I have invented a rolling mill which overcomes the above-mentioned disadvantages of the known mill construction. In accordance with my invention, I provide side guides on both sides of the mill and operate the guides successively to provide a parallel guiding throat on the entering side of the mill and a tapered guiding throat on the other side of the mill. The conditions of the guides on the two sides of the mills are reversed automatically by a change in the direction of the movement of the piece. Means are provided for adjusting the guides initially to cooperate with material of any desired width within the range of a particular construction.

My invention also includes means for flattening or leveling the leading end of the piece prior to engagement with the furnace coiler. This means takes the form of a series of flattening rolls adjacent the furnace mouth. In passing through the rolls, the end of the strip is straightened or flattened so that proper engagement with the furnace coiler is insured practically without exception.

I also provide pinch rolls for feeding the material toward the mill and, after passing through the mill, toward the coilers, between passes, whereby the strip is properly started on the latter. These pinch rolls are automatically raised when the strip has been properly started. They are also withdrawn when the material being rolled is handled back and forth through the mill in the flat without coiling between passes.

For a complete understanding of the invention, reference should be made to the accompanying drawings illustrating a present preferred embodiment thereof. It is to be understood, however, that other embodiments of the invention may be constructed within the scope of my broader claims. Referring to the drawings:

Figure 1 is a horizontal section through a mill having my invention incorporated therein showing parts in plan;

Figure 1A is a partial, sectional view similar to Figure 1 showing a slightly modified form of construction;

Figure 2 is a partial side elevation with the mill housings removed for the sake of clearness;

Figure 3 is a partial sectional view along the line III—III of Figure 2, showing parts in elevation;

Figure 4 is a partial, vertical section through the coiling furnace showing other parts in elevation to a slightly enlarged scale;

Figure 5 is a side elevation similar to Figure 4 showing a modified form of construction embodying pinch rolls particularly adapted for automatic operation, as well as flattening rolls;

Figure 6 is a vertical, sectional view along the line VI—VI of Figure 5 showing parts in elevation;

Figure 7 is a partial, sectional view along the line VII—VII of Figure 5;

Figure 8 is a schematic diagram of the automatic control system for the apparatus of Figures 5 through 7; and

Figure 9 is a similar view of the system for controlling the guides of Figures 1 through 3.

Referring in detail to the drawings, a mill 10 comprises housings 11 having windows 12 for receiving bearing chucks adjustably positioned therein. Backing rolls 14 and working rolls 15 are journaled in the chucks, the rolls preferably having anti-friction bearings, not shown. The housings 11 are connected by transoms 16.

Auxiliary housings 18 are positioned on opposite sides of the mill. Roll tables 19 extend between the housings 18 for conveying material to and from the mill rolls. Furnaces 20 having coilers 21 therein are positioned at a convenient distance from the mill. Tilting guides 22 are provided on the roll tables 19 for diverting material advancing through the mill from a hori-

zontal path of travel into the coilers 21. These coilers are simply spools of convenient size with suitable driving and control equipment, each spool having blades 23 positioned therein, as shown in Figure 4, so that when the leading end of the strip enters one of the coilers between adjacent blades 23, the rotation of the coiler bends the strip around the leading edge of one of the blades. As shown in Fig. 4, the coiling reel is driven in such direction that the blades on the lower side move in a direction opposite that in which the strip moves. The remainder of the strip is then drawn around a scale-breaking roll 24 at the edge of the furnace mouth and wound up on the coiler.

A base 25 is carried between each of the auxiliary housings 18. Bottom guides 26 are pivotally supported on the bases 25 at 27. The guides 26 are also supported by flat seats 28.

Top guides 29 are pivoted at 30 to the transoms 16 and are suspended from angle bars 31 extending across the mill between the chucks 13 for the top backing rolls, by links 32. The inner ends of the guides 26 and 29 are shaped to conform closely to and are actually in contact with the work rolls to effect a stripping action in case the piece tends to follow around the periphery of one or the other of the rolls.

In the subsequent description of the invention, I shall refer specifically to the equipment on the right-hand side of the mill only, as shown in Figures 1, 2 and 4, but it will be understood that duplicate equipment is employed on the opposite side of the mill.

Screw shafts 33 are slidably mounted in the housing 18 parallel to the axes of the mill rolls. Side guides 34 are supported on the screw shafts 33 by hinged joints 35. The guides 34 have a plane inner surface 36 with recesses into which anti-friction rolls 37 are let. The mill ends of the guides extend to a point closely adjacent the rolls, as shown in Figures 1 and 2. The outer ends of the guides are pivotally supported on nuts 38 traveling on a screw shaft 39 journaled in the side frames of the table 19. The ends of the screw shaft 39 are oppositely threaded so that on rotation of the shaft, the outer ends of the guides are moved toward or away from the center line of the table 19.

From what has been said, it will be apparent that my invention provides side guides which may be disposed in parallel relation, as shown on the left-hand side of the mill in Figure 1, or in angular relation, as shown on the right-hand side of the mill in Figure 1, for the purposes, respectively, of definitely and positively guiding the leading end of an advancing strip into the rolls at the proper angle thereto, and providing a tapering throat for receiving the end of the piece as it emerges from the mill. I shall now describe the mechanism for operating the guide supports to bring about the proper relation of the guides at the proper time.

The outer ends of the guides may be adjusted toward or away from each other through the shaft 39, as already described. This adjustment is effected by a hand wheel 40 having a pinion 41 meshing with a gear 42 along the screw shaft 39. A suitable pedestal bearing 43 is provided for the hand wheel shaft 44. The outer ends of the guides 34 are adjusted manually to the proper spacing before commencing the rolling.

The adjustment of the inner ends of the guides 34 is effected through the screw shafts 33. Gear cases 45 attached to the housings 18 enclose gear wheels 46 having their bores threaded for engagement with the shafts 33, and pinions 47 keyed to shafts 48. Hand wheels 49 permit manual adjustment of the screw shafts 33. These shafts are normally driven from extensions 50 of the shaft of one of the rolls 51 of the table 19. The rolls of the table are driven from a line shaft 52 through the usual bevel gears by a reversing motor, not shown. Between the shaft extensions 50 and the shafts 48 are positioned friction clutches 53 and jaw clutches 54 having operating levers 55. The purpose of the friction clutches is to permit the rotation of the shaft 48 to be arrested after a predetermined movement thereof without stopping the operation of the roll 51. The jaw clutches 54 permit the shafts 33 to be freed from the table drive while being manually adjusted.

The friction clutches 53 have detents 56 thereon cooperating with stops 57 on the housings 18 to limit rotation of the shaft 48 to the desired extent. After the detents engage the stops, the adjustment of the shafts 33 ceases but the roll 51 continues rotating with accompanying slippage of the clutches 53.

It will now be apparent that once the outer ends of the guides 34 have been adjusted, the inner ends of the guides will be spread to form a tapering throat or moved together to parallel position with the reversal of the drive for the rolls of table 19. The detents and stops controlling the amount of rotation of the friction clutches will determine the amount of movement imparted to the inner ends of the guides and may, if desired, be made adjustable. It will be understood, of course, that the guide-operating mechanism is designed so that the guides will be spread at the mill end when the table rolls are driven in such a direction as to move material away from the mill. At the same time, the guides on the opposite side of the mill will be actuated to parallel position. In this way, the material advancing toward the mill is definitely and positively alined at right angles to the plane containing the axes of the mill rolls. The emerging material is in no wise obstructed but is gently received within a slightly tapering guiding throat. In both cases, the anti-friction rolls 37 prevent binding and insure continuous, steady forward movement of the material without grabbing or slipping. As before stated, the extreme positions of the inner ends of the guides may be adjusted initially by hand after disengaging the clutches 54. Thereafter, the range of movement of the inner ends of the guides is determined by the location of the detents 56 and stops 57. In the construction illustrated, I have assumed that one complete revolution of the shaft 58 will produce the necessary movement of the inner ends of the guides.

Referring now particularly to Figure 4 for a disclosure of the flattening rolls, housings 60 supported on side members of the roll table 19 have bearing chucks 61 movable vertically therein by means of a pneumatic cylinder 62. Rolls 63 and 64 journaled in the chucks 61 cooperate with adjacent rolls 65 of the table 19. A roll 66 also journaled in the chuck 61 cooperates with a roll 67 journaled in adjustable chucks 68. The chucks 68 are actuated by pneumatic cylinders 69.

The rolls 63 and 65 may be driven and when the former is lowered into engagement with the latter, they serve as pinch rolls to feed the strip toward the mill from the coiler 21. When the

strip has been started through the mill and engages the coiler on the opposite side thereof, the chucks 61 are preferably raised and the rolls 63, 64 and 66 lifted off the strip. The chucks 68 of the rolls 67 are preferably lifted at the same time as the chucks 61. In its normal lower position, however, the roll 67 is effective to assist in flattening or leveling the leading end of the material in its passage from the mill to the coiler. The pinch rolls 63 are lowered, of course, at this time. If the leading end, after passing through the pinch rolls, is deflected downward, it will engage the roll 67 and then the roll 65. On passing between the rolls 64 and 65, the end will be flattened sufficiently to engage the coiler 21 without difficulty. Similar results occur if the leading end of the piece is deflected upward, in which case it will engage the rolls 66 and 64 successively, and after passing between the roll 64 and the roll 65 cooperating therewith, will be found to be satisfactorily flattened. The control of the fluid supplied to the cylinders 62 and 69 has not been illustrated since it may be of any desired character, automatic or manual.

Figure 1A illustrates a modified form of actuating mechanism for the guides 36. This means takes the form of pistons 70 reciprocable in cylinders 71 by means of fluid pressure, hydraulic or pneumatic, supplied thereto. The pistons 70 have piston rods 72 attached thereto corresponding to the screw shafts 33 and functioning in the same way, under the influence of fluid pressure admitted to either side of the cylinders 71 for actuating the guides.

A modified form of construction of the auxiliary rolls for feeding and flattening the strip is shown in Figures 5 through 7. A roll table 73 has side frame castings 74. Housings 75 are attached to the castings 74 and have windows 76 therein in which bearing chucks 77 are slidable. Cylinders 78 formed in the upper part of the housings 75 have pistons 79 reciprocating therein. Piston rods 80 attached to the pistons 79 are threaded into the chucks 77 whereby the latter may be lifted to the dotted line position shown in Figure 5. Piston rods 80 extend outwardly through the upper end of the cylinders 78 and are connected by cross beams 81. Cylinders 82 carried on a transom 83 extending between the housings, also have pistons and piston rods arranged as shown in Figure 6 whereby the beams 81 and, therefore, the chucks 77, may be raised through a small distance. The piston rods of the cylinders 82 have separable, abutting engagement with bolts 81a. It will be apparent that the cylinders 79 and 82 provide independent means for lifting the chucks 77 through a long stroke and a short stroke, respectively. The object of this arrangement will become apparent as the description proceeds.

An equalizing shaft 84 extends between the housings 75 and is journaled therein. Cranks 85 keyed to the shaft 84 carry trunnions 86 in slidable bearings blocks 87. The trunnions 86 are threaded into the chucks 77, as best shown in Figure 6. The equalizing shaft obviously serves to effect simultaneous and equal movement of both bearing chucks and prevents binding of the reciprocating mechanism.

A top pinch roll 88 is journaled in the chucks 77 for cooperation with a bottom pinch roll 89, which may conveniently be one of the rollers of the table 73. Flattening rolls 90 and 91 are also journaled in the chucks 77. The roll 91 cooperates with a roll of the table 73. A roll 92 is journaled in chucks 93 slidable vertically in the base portions of the housings 75. Cylinders and pistons 94, bell crank linkage 95 and struts 96 are provided, as shown in Figure 5 to effect vertical movement of the chucks 93 for a purpose which will appear later.

As best shown in Figure 7, the roll 90 is journaled in chucks 97 secured to the chucks 77. A contact-actuating rod 98 is threaded into a projection 99 from one of the chucks 93. The rod 98 also passes through guides 100 projecting from one of the chucks 97. The rod 98 controls the engagement of a moving contact 101 with a fixed contact 102 on one of the chucks 77 for a purpose which will presently appear.

The chucks 93 are normally lowered so that contact 101 engages contact 102. These contacts control a circuit for stopping the main mill motor in case of breakage of the strip. When the strip is being rolled, the rolls 88, 90 and 91 rest on the strip and are spaced thereby from the rolls 89 and 92. After the strip has been entered into the mill so as to separate the pinch rolls 88 and 89, fluid is admitted to the cylinders 94 to cause the chucks 93 to be raised until the roll 92 engages the lower surface of the strip. The rolling operation then proceeds. If breakage of the strip should occur, the continuing fluid pressure in the cylinders 94 causes the chucks 93 to rise until the roll 92 actually engages the roll 90. This causes the rod 98 to move upwardly and lift contact 101 out of engagement with contact 102. Separation of these contacts, through suitable auxiliary equipment, causes stoppage of the main mill motor.

The cylinders 79 and 82 are automatically controlled to cause the pinch rolls 88 and 89 to engage the material at certain times and to release it at other times.

In rolling a slab into strip on the mill 10, it is desirable that the pinch rolls 88 be withdrawn as long as the slab being reduced has sufficient rigidity to permit it to be fed back and forth to and from the mill by the friction of the table rolls. When the slab has been reduced to a gauge such that it has relatively little rigidity, or to a condition in which coiling between passes is advisable, the pinch rolls are advanced to assist in threading the strip through the mill at the beginning of each pass. While both ends of the strip actually pass through the mill, the pinch roll motors are so controlled that neither end of the strip is disengaged from the pinch rolls on both sides of the mill. At least one end of the strip is always engaged by at least one set of pinch rolls. It is by these pinch rolls that the strip is then fed back to the mill for the next pass. On the exit side of the mill, the pinch rolls assist in delivering the leading end of the strip into the coiler by pushing it up the guide 22.

The system for automatically controlling the pinch rolls will be now explained with reference to Figure 8. In Figure 8, the work rolls of the mill are indicated by the same numeral as in Figures 1 and 2. A motor 103 is provided for driving the mill and the power of the motor may be applied directly to the work rolls 15 or to the backing rolls 14. The motor 103 may be controlled by any suitable control system. For simplicity, I have only illustrated a control panel 104 having incoming power leads, outgoing motor leads, and outgoing control leads extending to a controller 105. The panel 104, of course, will be provided with suitable relays and contactors effective under the control of the controller 105 to cause starting of the motor 103.

The panel 104 also has a relay 106 effective when deenergized to cause stopping of the motor. The specific details of such an arrangement are known and need not be included here. The controller 105, obviously, is effective on being shifted manually in one direction or the other, to cause operation of the motor 103 to drive the mill rolls 15 and thus move the strip through the mill in the desired direction. The supply of fluid to the cylinders 78, 82 and 94 is controlled by a master valve 107 and auxiliary valves 108 and 109. The valve 107 has operating magnets 110 and 111 and the valve is of such character that it remains in the position to which it was last operated until positively actuated therefrom. The valves 108 and 109 have operating magnets 112 and 113. The arrangement of these valves and their operating magnets is such that they remain in the illustrated position until the magnets are energized, and return to the illustrated position when the magnets are deenergized.

The valve 107 is controlled by a limit switch 114 operated by any convenient means, in accordance with the position of the mill screwdowns which determine the thickness of the pass between the rolls and the material itself after passing through the mill. When the space between the mill rolls 15 is greater than a predetermined value, say ¾", the limit switch 114 closes its lower contacts to energize the magnet 111 and move the valve 107 so that fluid under pressure is supplied from a reservoir 115 through suitable piping, to the cylinders 78 on both sides of the mill. The pistons 79 are thereby actuated full stroke to withdraw the upper pinch roll 88 and provide ample free space for the passage back and forth to and from the mill of the slab in the initial stages of its reduction to strip.

When the thickness of the slab has been reduced to a point such that, on the next pass, the mill rolls are spaced apart only ¾" or less, the partially reduced material is sufficiently thinned and elongated to permit of coiling and, at the same time, its rigidity is such that the assistance of the pinch rolls is required to manipulate it through the mill and into the coilers. The limit switch 114 then closes its upper contacts to energize the magnet 110 and operate the valve 107 to the illustrated position. This vents the cylinder 78 and the pistons 79 immediately drop to lower the pinch rolls 88 onto the material. The pinch rolls are driven by any convenient means, at the same peripheral speed as the rolls 15, so as to cooperate therewith in moving the material back and forth.

If it is assumed for the sake of explanation that the breakdown formed from flat rolling the slab was reduced on a pass from left to right, to a gauge such that after the next reduction, it would be less than ¾" thick, as soon as the top roll 15 is lowered to within less than ¾" of the bottom roll, the described operation of the valve 107 will take place and the pinch rolls will seize the breakdown for the next pass from right to left. When all is ready for this pass, the roller operates the handle of the controller 105 to the left, as shown in Figure 8, whereupon the motor 103 is operated so as to drive the rolls 15 and roll the strip from right to left. The pinch roll drive is so coordinated with that of the mill that the pinch rolls 88 are simultaneously operated so as to assist in the feeding of the breakdown.

The movement of the controller 105 bridges contacts 116 to energize a relay 117. The relay 117 has a time delay in its operation, indicated by a dashpot, and after a certain time bridges contacts 117*a* to energize the magnet 113. The relay is adjusted so that the contacts 117*a* will be bridged just after the leading end of the breakdown being rolled passes between the rolls 15. The magnet 113 operates the valve 109 to admit fluid supplied through the valve 107 to the cylinders 82 on the entering side of the mill. The pinch roll 88 on that side is thus lifted from the material.

After a slightly longer time, the relay 117 operates to bridge its contacts 117*b*, maintaining the circuit for the magnet 113 by reason of the fact that the bridging contact slides along the contacts 117*a*. The relay is adjusted so that the contacts 117*b* are bridged after the material has emerged from the mill on the exit side, passed through the pinch rolls, and made one turn about the coiler. The bridging of the contacts 117*b* causes the operation of magnet 113 to shift the valve 109. The cylinders 82 on the exit side of the mill thus operate to raise the associated pinch roll from the strip. The strip is thus free between the winding and unwinding coilers, except where engaged by the mill.

The operation of the valves 109 and 108 described above, also causes the operation of the cylinders 94 on opposite sides of the mill. The roll 92 is thus raised into engagement with the material but is sufficiently spaced thereby from the roll 90 that the contact 101 remains in engagement with the contact 102. The fluid pressure is continuously applied to the cylinders 94 as long as the rolling continues but, unless the strip breaks during rolling, the rolls 90 and 92 are maintained separated and the contacts 101 and 102 remain in engagement. If the strip is broken, the roll 92 is immediately lifted into engagement with the roll 90, whereupon the rod 98 lifts the contact 101 to open the circuit for the relay 106 and thereby stop the motor 103.

When the pass is completed, the controller 105 is restored to neutral position so that the trailing end of the strip stops between the mill and the pinch rolls on the exit side thereof. The relay 117 is thus deenergized and substantially immediately opens its contacts to deenergize magnets 112 and 113. The cylinders 82 are thus exhausted to the atmosphere and the pinch rolls dropped. At the same time, the cylinders 94 are exhausted through check valves 118, the weight of the roll 92 and chucks 93 serving to force the accumulated fluid out of the cylinders. The operating fluid for the cylinders 94 passes initially through expansion valves 119 which slightly delays the lifting of the chucks 93 on starting a pass.

The next pass is accomplished in exactly the same manner. Reversal of the controller 105 energizes the relay 120 and this, in turn, causes sequential lifting of the pinch rolls 88 on the entering and exit sides of the mill. This cycle is repeated until the strip has been reduced to the desired gauge, when it is wound on a coiler beyond the furnace on the exit side of the mill. The top work roll is then lifted by reversal of the screwdowns. The switch 114 closes its lower contacts and operates the valve 107 to admit fluid under pressure again to the cylinders 78, whereby the pinch rolls 88 on both sides of the mill are lifted out of the way for the next flat rolling operation.

Figure 9 shows how the side guide actuators of Figure 1A are controlled. When the controller 105 is shifted so as to cause the material to be fed from left to right, it closes contacts 121. It will be understood that operation of the controller also, through appropriate relays, causes the starting of the motor 103 in the proper direction. The closing of the contacts 121 energizes an operating magnet 122 for a valve 123. This valve is similar to that shown at 107 of Figure 8. The energization of the magnet 122 operates the valve to the position illustrated in Figure 9, in which it delivers fluid under pressure to the inner ends of the cylinders 71 on the exit (left-hand) side of the mill, and to the outer ends of the cylinders on the entering (right-hand) side of the mill. The guides 36 on the entering side are thus closed in, as indicated in Figure 9, while the guides on the exit side are opened to permit free passage of the material as it emerges from the mill.

On the reversal of the direction of rolling, for the next pass, the controller 105 bridges contacts 124 and energizes a magnet 125 to shift the valve 123 to the other position. The reverse operation of the cylinder 71 then takes place to close the guides on the left-hand side and open the guides on the right-hand side.

It will be understood that only a single controller 105 is employed and that it controls contacts 116 and 124, for example, simultaneously, in addition to the other contacts necessary to bring the motor 103 up to operating speed. The system of Figure 9 is shown separately from that of Figure 8 simply because it is a diagrammatic plan, whereas the latter is a diagrammatic elevation, but it will be understood that the two systems are combined and under the common control of the controller 105.

It will be apparent from the foregoing description that my invention provides a rolling mill having numerous advantages over known apparatus of the same kind. In the first place, the slab or strip is definitely guided into the mill along the pass line or longitudinal axis of the mill. There is thus no possibility for the strip to move into the rolls crabwise at a slight angle to the pass line. Cambering of the strip or slab is thus prevented. Free movement of the highly flexible, thin strip from the mill is permitted without obstruction since the guides on the exit side of the mill are automatically retracted to form a tapering guiding throat. The positions of the guides on opposite sides of the mill are reversed automatically with the reversal of the roll tables and the mill so that once the guides have been adjusted, they require no further attention until a different width of material has to be rolled.

The flattening rolls insure that the leading end of the strip will always be sufficiently flat to enter and engage the coiler properly to wind the strip thereon. This avoids the delays experienced heretofore incident to the backing up of the strip and repeating the entry thereof into the coiler after a first unsuccessful attempt.

The top and bottom guides 29 and 26 respectively, with the side guides 34, form a complete guide box and prevent any departure of the strip from the pass level or the horizontal plane through the roll pass. With the guides of my invention, improper entry of the material into the mill is rendered almost impossible. The top guide may be adjusted by a turnbuckle in the links 32. The bottom guide may be similarly adjusted by shimming up the outer end thereof which rests on the seat 28.

The automatic control of the pinch rolls on both sides of the mill insures that the strip will be advanced properly into the mill and, on emerging therefrom, into the coiler, whereupon the pinch rolls will be lifted out of the way when there is no further need for them. The automatic stop mechanism prevents loss, damage or injury in case the strip breaks during a pass.

The positive actuation of the side guides under the control of the main controller causes the strip to be properly started toward the mill and correctly positioned with respect thereto before it actually enters between the mill rolls, after which no effort is sufficient to correct an improper starting of the strip, because of the great force exerted on the strip by the rolls.

The top guide 29 has an important function in preventing the coiling up of the leading end of the piece when rolling in the flat. If it were not for this guide, the slab, in the early stages of its reduction, might bend up sufficiently to escape the side guides altogether, whereupon it might be improperly entered into the mill pass on the next reversal.

Although I have illustrated and described only one embodiment of my invention, it will be apparent that numerous changes therein may be made without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. In a rolling mill, side guides extending therefrom, pivoted supports for the outer ends of the guides, means for adjusting said supports toward or away from each other, a roll table for feeding material to and from the mill, and means driven from a roll of said table for moving the inner ends of the guides toward and away from each other.

2. In a rolling mill, a pair of side guides pivotally supported adjacent their outer ends, axially movable screw shafts hinged to the guides adjacent their inner ends, a roll table for moving material to or from the mill, means for shifting said screw shafts including nuts thereon, means for driving the roll table, and means including a friction clutch whereby said drive also actuates said nuts.

3. The combination with a hot strip mill and a coiler adapted to receive strip from the mill and wind it into a coil, of means between the mill and the coiler for flattening the leading end of the strip passing from the mill to the coiler.

4. The apparatus defined by claim 3 wherein said flattening means comprises a plurality of leveling rolls.

5. In a method of making strip, the steps including rolling down a hot slab into an elongated strip, coiling the strip between rolling passes, and flattening the leading end of the strip before coiling between passes.

6. In a rolling mill including a pair of housings and work rolls journaled therein, pinch rolls on one side of the mill, and means for raising one of the pinch rolls through a short distance, and independent means for raising the upper pinch rolls through a greater distance.

7. The combination with a rolling mill, of pinch rolls on one side of the mill, one of said rolls being retractible, a motor for driving the mill, a controller for the motor, and means operated by said controller for causing retracting movement of said one of said pinch rolls at a

predetermined time after the starting of the mill motor.

8. The combination with a rolling mill, of pinch rolls on at least one side of the mill for feeding material thereto, one of said pinch rolls being retractible, and means actuated by the setting of the mill for passes of various thickness, whereby to operate said retracting means.

9. The combination with a rolling mill having an adjustable upper roll, of pinch rolls for feeding material to the mill, one of said rolls being retractible, and means operated in accordance with the adjustment of the upper mill roll for controlling retraction of said pinch roll.

10. The combination with a rolling mill having a driving motor and a controller for the motor, of adjustable side guides on both sides of the mill, and means operated by said controller for shifting the guides inwardly on the entrance side of the mill and outwardly on the exit side of the mill.

11. The combination with a rolling mill and a roll table for feeding material thereto, a motor for driving the mill, of a pair of pinch rolls adapted to engage material on the table, at least one of said pinch rolls being movable, means for constantly urging said movable roll into engagement with the material, and means actuated by movement of said movable roll toward the other of said pinch rolls for stopping said motor.

12. The combination with a rolling mill having a driving motor, of a pair of pinch rolls adapted to engage the material moving to or from the mill, one of said rolls being movable, means for normally holding said movable roll in engagement with the material, and means actuated by movement of said one of said rolls into engagement with the other of said rolls for stopping said motor.

13. The combination with a rolling mill, a driving motor therefor and a controller for the motor, of pinch rolls on one side thereof, one of said rolls being movable, means tending to hold said movable roll against the material being rolled, and means responsive to movement of the roll on breakage of the material for stopping the mill motor.

14. The combination with a rolling mill, a driving motor therefor and a controller for the motor, of pinch rolls on one side thereof, one of said rolls being movable, means tending to hold said movable roll against the material being rolled, means responsive to movement of the roll on breakage of the material for stopping the mill motor, and means operated by movement of the controller to start the motor, for rendering said first-mentioned means effective.

15. The combination with a reversing strip mill, and pinch rolls on opposite sides thereof for feeding material to and from the mill, of a pair of side guides on each side of the mill between the mill and the pinch rolls, means pivotally supporting the outer ends of said guides for swinging movement in a horizontal plane, and means for so moving the inner ends thereof as to dispose the guides on the entry side of the mill in parallel relation and those on the exit side of the mill at an angular relation, depending upon the direction of movement of the material through the mill, said first mentioned means being so spaced as to permit the strip to pass freely between the ends of the guides on the exit side and enter the pinch rolls.

16. In a strip mill, a controller for reversing the direction of rotation of the mill, side guides pivoted adjacent their outer end, and means operated by said controller for adjusting the inner ends of the guides toward or away from each other, according to the direction of rotation of the mill.

17. In a strip mill, a pair of side guides on each side of the mill, pinch rolls adjacent the outer ends of the guides and means controlled by the direction of movement of material passing through the mill effective to cause the guides on the entering side to move to parallel relation, and those on the exit side to move to an angular relation forming a tapering throat with its narrowest portion adjacent the pinch rolls whereby accurately to center the material entering the pinch rolls and preventing cambering of the material.

18. In a rolling mill, a pair of housings having work rolls journaled therein, pinch rolls on at least one side of the mill for engaging material being worked in the mill, means for retracting one of said pinch rolls when unused for a substantial period, and independent means for temporarily retracting one of said rolls.

19. The combination with a rolling mill and a roll table for advancing work thereto, of pinch rolls on one side of the mill, one of said pinch rolls being retractible, and means for retracting said roll including fluid pressure-operated cylinders and pistons, one of which has a short stroke for temporarily retracting the roll and the other having a longer stroke for retracting the roll when unused for substantial periods.

20. Strip rolling apparatus comprising a mill, pinch rolls on opposite sides thereof for feeding material to and from the mill, guides between the mill and the pinch rolls, and means for positioning the guides on the entering side of the mill parallel to the pass line whereby to guide positively the material advancing to the mill, said means being also effective to set the guides on the exit side at a slight angle to the pass line forming a converging throat to receive material issuing from the mill and guide it into the pinch rolls while maintaining it centered relative to the pass line.

ALONZO B. MONTGOMERY.

July 13, 1937. A. B. MONTGOMERY 2,087,065

METHOD AND APPARATUS FOR ROLLING

Filed Jan. 19, 1934

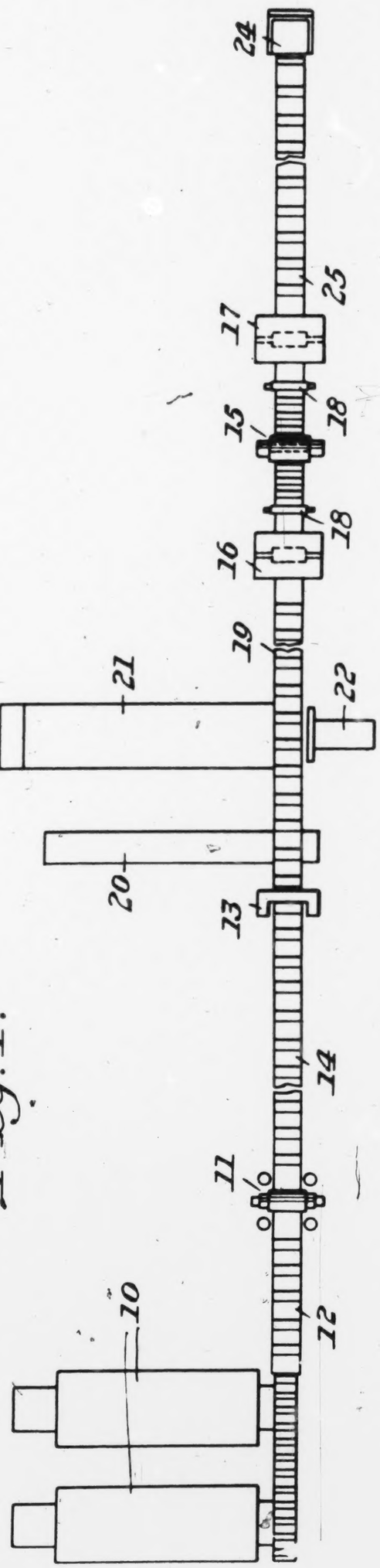


Fig. 1.

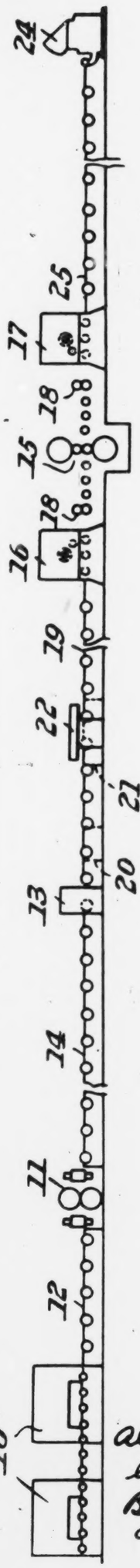


Fig. 2.

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METHOD AND APPARATUS FOR ROLLING

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Application January 19, 1934, Serial No. 707,401

5 Claims. (Cl. 80—40)

My invention relates to the rolling of metal and particularly to long lengths of thin sheet metal, such as strip.

In the U. S. patent granted July 18, 1933 to Keeney, et al., No. 1,918,968, there is disclosed a four-high reversing mill with heating furnaces on opposite sides thereof for hot rolling strip. My invention is concerned chiefly with improvements upon the method and apparatus disclosed in said patent.

For certain classes of product, it is desirable to provide a finish on the hot strip superior to that which can be obtained with the mill shown in the Keeney patent, in which the entire reduction from the slab to the strip is effected by the same rolls. In order to roll a slab in the Keeney mill, the slab must be highly heated, specifically, above the temperature at which free scaling occurs. The presence of the scale on the slab roughens the rolls and precludes the obtaining of a high finish on the hot strip of final gauge. The rolls thus wear rapidly and require frequent changing. The output, furthermore, is limited because of the fact that the slabbing operation is necessarily slow due to the frequent reversals of the mill, and full advantage of the capacity of the four-high mill for high-speed operation is realized only during a portion of the operating cycle, namely, during the rolling with coiling.

In rolling strip from slabs on the Keeney mill, in addition, the effect of the edging rolls used to control and assist in the removal of scale, is to cause the production of ears or projections at the corners of the slab as it is reduced to strip form. These ears make it difficult to direct material on to the coiler for the continuation of the hot rolling.

In accordance with my invention, I take a slab after it has been properly heated in a suitable furnace and subject it to repeated passes through a universal mill to elongate it considerably without materially increasing its width. The ends of the piece are then sheared off to remove the ears projecting therefrom. The material is then passed into another reversing mill, e. g., that of the Keeney patent, with heating furnaces on opposite sides thereof, where it is subjected to further rolling with coiling between passes. After the material has been reduced sufficiently in the four-high mill, it is wound on a final coiler.

For a complete understanding of the invention, reference is made to the accompanying drawing illustrating diagrammatically a present preferred embodiment of the invention and the method of its practice.

Referring in detail to the drawing, furnaces 10 are provided for heating slabs for delivery to a universal mill 11. As is well known, the universal mill is a two-high reversing mill with one or more pairs of vertical rolls or edgers. A roll table 12 extends from the furnaces to the mill. A slab shear 13 is positioned at a suitable distance ahead of the mill 11 with a connecting roll table 14 therebetween.

A second reversing mill 15, preferably but not necessarily a four-high mill, has coil-heating furnaces 16 and 17 on opposite sides thereof, and pinch rolls 18 between the coil furnaces and the mill rolls. A roll table 19 connects the shear 13 and the mill 15. A crop conveyor 20 and a slab conveyor 21, with an associated pusher 22, extends laterally from the table 19. A hot strip coiler 24 is located beyond the mill 15. Roll tables 25 connect the mill 15 and the coiler 24.

The operation of the apparatus above enumerated to perform the method of my invention, may be described briefly as follows: The slabs are fed into the furnaces 10 to be heated prior to rolling in the mill 11. The slabs are initially 2" to 14" thick and of suitable width and length to provide the desired dimensions of finished hot strip. The heated slabs are passed back and forth through the universal mill 11, which effects a slabbing operation, until the slab is reduced to a thickness of ½" or less, with a corresponding elongation, and is cooled to a point where free scaling substantially ceases. The partially reduced slab is then forwarded to the four-high mill 15. The ends of the hot slab, however, are sheared off by the shear 13 before the piece arrives at the coiling mill.

Generally, I prefer to perform all slabbing operations on the mill 11 and thereby reduce the material to a gauge suitable for coiling before advancing it to the mill 15. The material enters the mill 15 while still hot and is coiled up in the coil-heating furnace 17 after the first pass through the mill. On the next pass, the material is coiled in the heating furnace 16. This cycle is repeated and the partially reduced slab is gradually elongated to strip form, the heat lost from the strip by radiation, and otherwise, being supplied during the interval it dwells in the coil-heating furnaces.

When the strip has been reduced to final gauge, say .065", it is advanced from the mill 15 in the flat form along the table 25 toward the final coiler 24. After the strip has been coiled on the coiler 24, and cooled, it is ready for shipment

or further processing, for example, by cold rolling

While I have stated that it is preferable to perform all the slabbing operations on the mill 11, it is possible that in certain cases it may be desirable to effect some reduction of the material in the flat on the mill 15.

It will be apparent to those skilled in the art that the invention described is characterized by numerous advantages over the practice and apparatus heretofore employed. In the first place, a higher finish can be obtained than by using the four-high mill for both slabbing and coiling operations. Since the slabbing operation is confined to the universal mill, by far the greatest portion of free scaling has occurred before the material reaches the four-high mill, at which time it is characterized by a tight, thin layer of oxide which adheres to the strip throughout the further rolling. Excessive accumulation of scale in the four-high mill is thus prevented, as well as the resulting injury to the surface of the working rolls. The output of the four-high mill is increased from 25 to 30%, furthermore, because of the fact that it is operating at high speeds a greater portion of the time than when slabbing operations are effected therein. The high speeds of which the mill is capable, of course, can best be taken advantage of when rolling the longer lengths. The reduction in the wear on the rolls of the four-high mill makes it unnecessary to change rolls as frequently as has heretofore been the case. The shearing of the ends of the partly reduced slab before rolling, greatly facilitates the entry of the material into the furnace reels, making the operation of the mill 15 more efficient and avoiding the delays and loss of material incident to repeated efforts to cause the end of the piece to engage the reel. While I have described the cropping of the ends of the slab as taking place between the slabbing and the rolling with coiling, it is obvious that where some slabbing is done on the four-high mill, the shearing may be performed after such final slabbing.

Although I have illustrated and described but a single preferred embodiment of my invention with certain possible modifications thereof, it will be understood that numerous changes in the apparatus and practice disclosed may be made without departing from the spirit of my invention or the scope of the appended claims.

I claim:

1. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body in the roughing mill until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, and, in the same heat, feeding the thinned body to a reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.

2. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body in the roughing mill until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, trueing the edges in said mill, and, in the same heat, feeding the thinned body to a reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.

3. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body back and forth in the roughing mill until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, and, in the same heat, feeding the thinned body to a reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.

4. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body in the roughing mill until the body cools to a temperature below that at which free scale forms, and until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, and, in the same heat, feeding the thinned body to a reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.

5. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body in the roughing mill until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, and, in the same heat, feeding the thinned body to a reversing mill after cropping at least one end of the thinned body to facilitate its entry into said reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.

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Sept. 10, 1940. A. B. MONTGOMERY 2,214,107

METHOD OF ROLLING

Filed Oct. 23, 1936 6 Sheets-Sheet 1

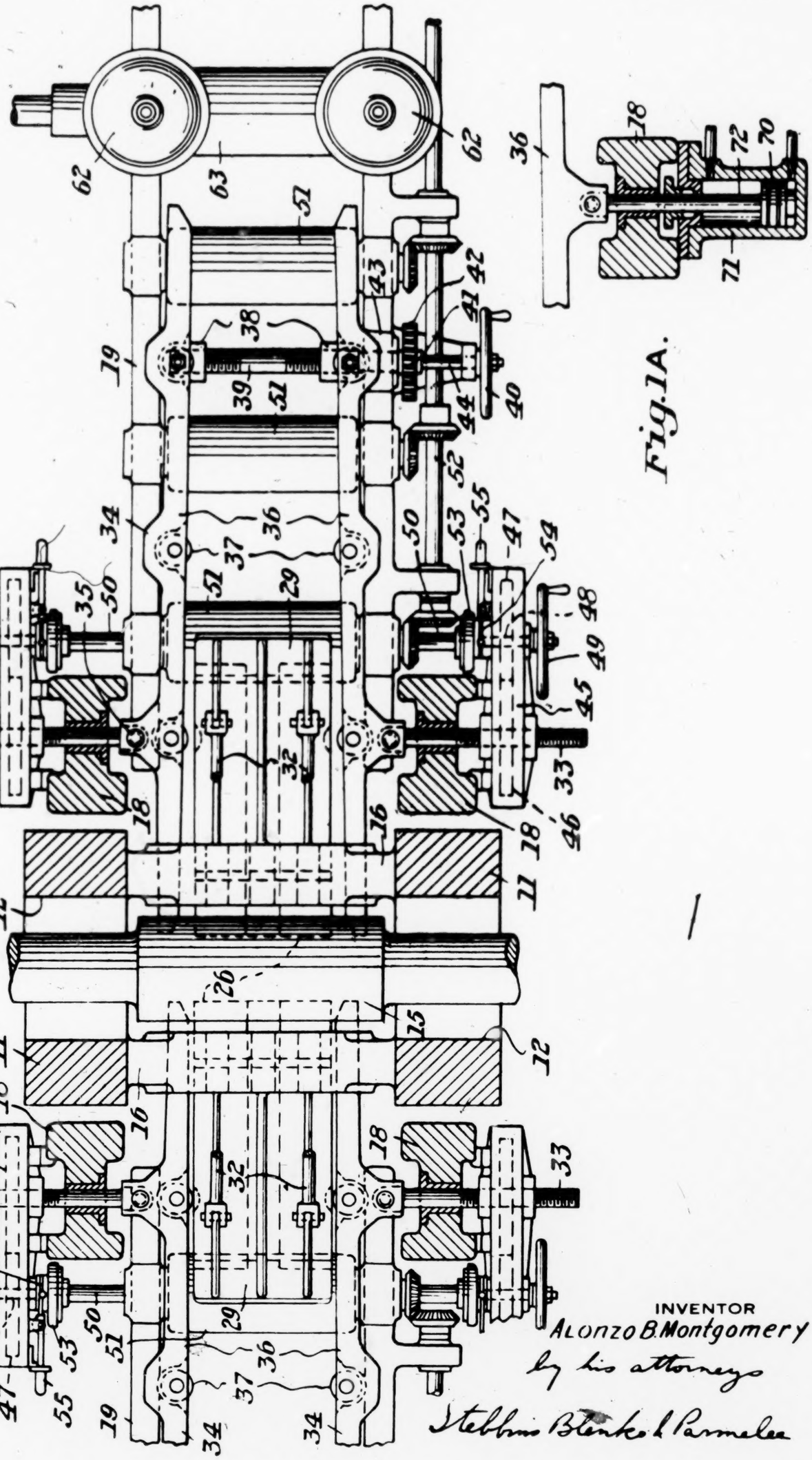


Fig. 1.

Fig. 1A.

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Fig. 3.

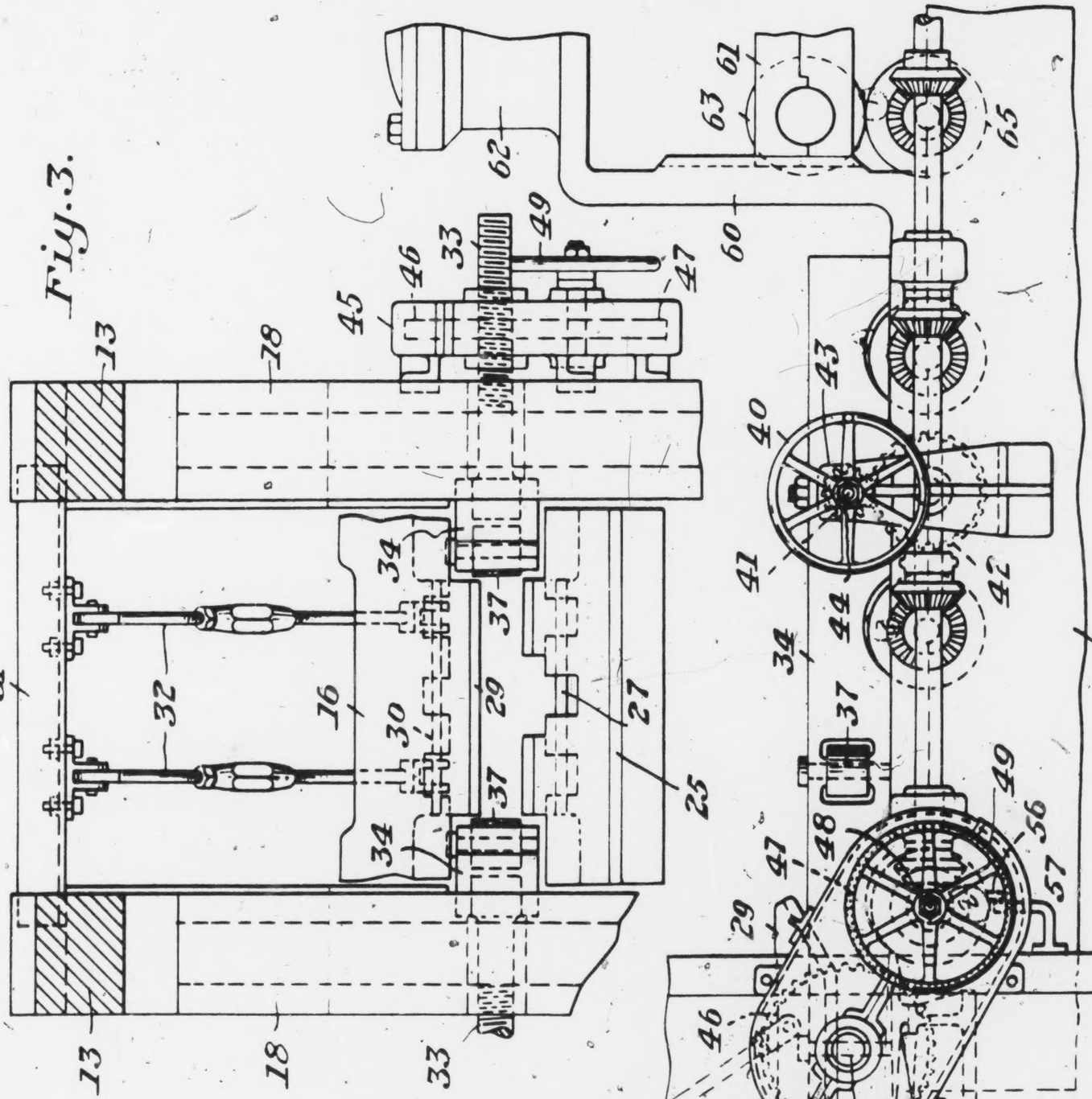
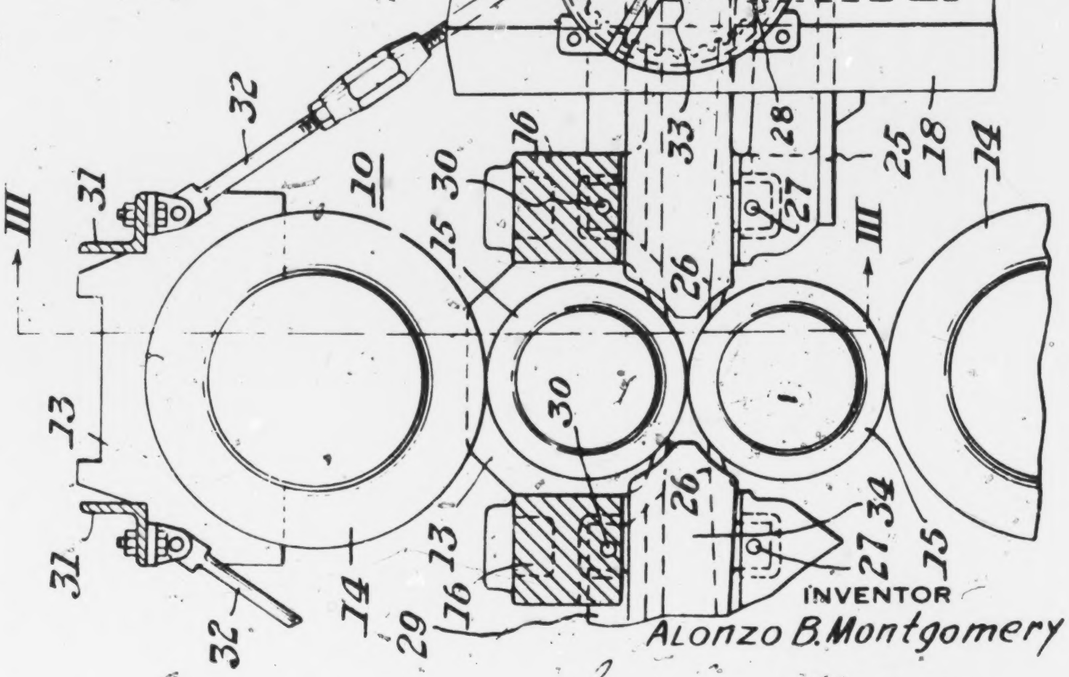


Fig. 2.



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METHOD OF ROLLING

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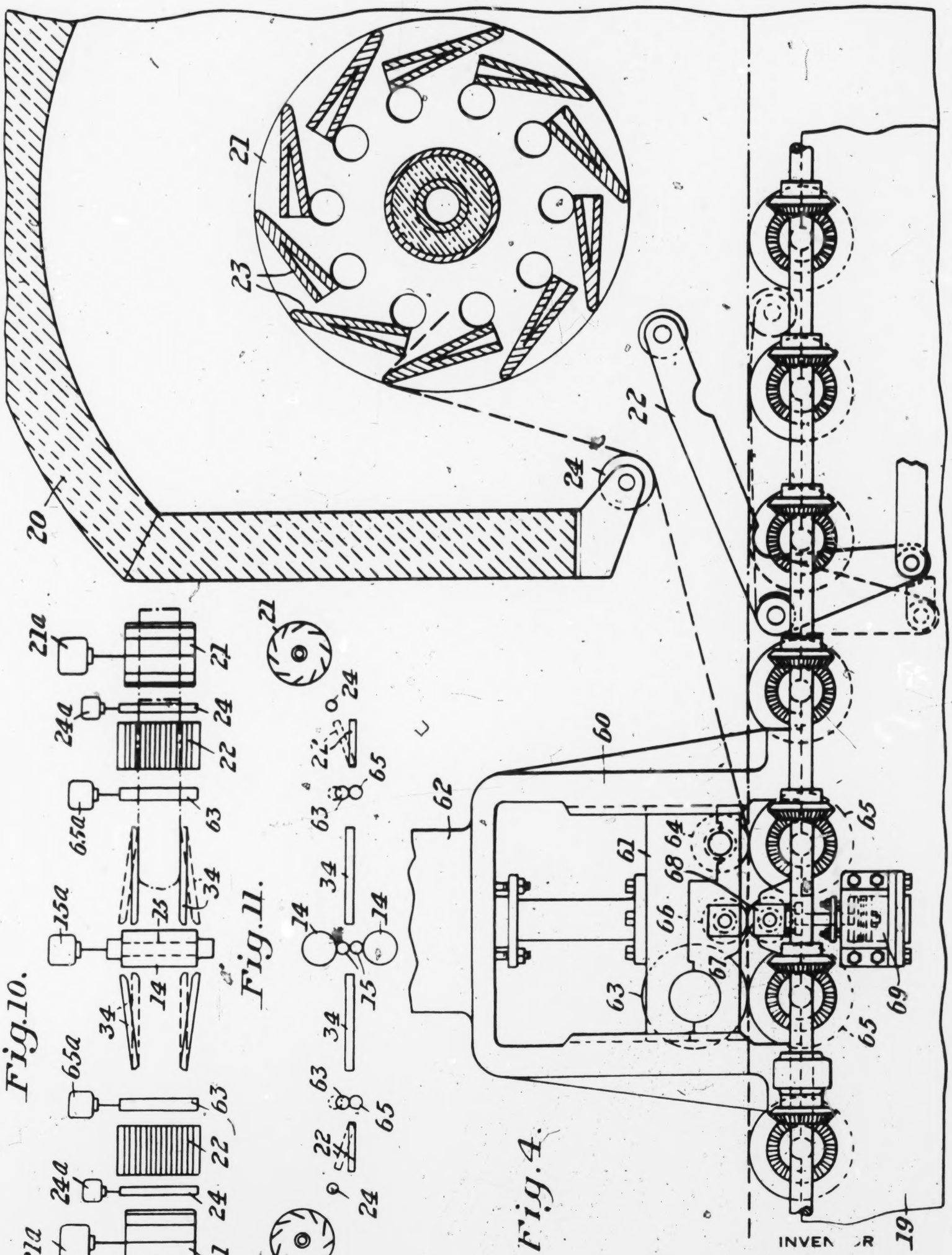


Fig. 4.

Fig. 10.

Fig. 11.

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METHOD OF ROLLING

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Fig. 7.

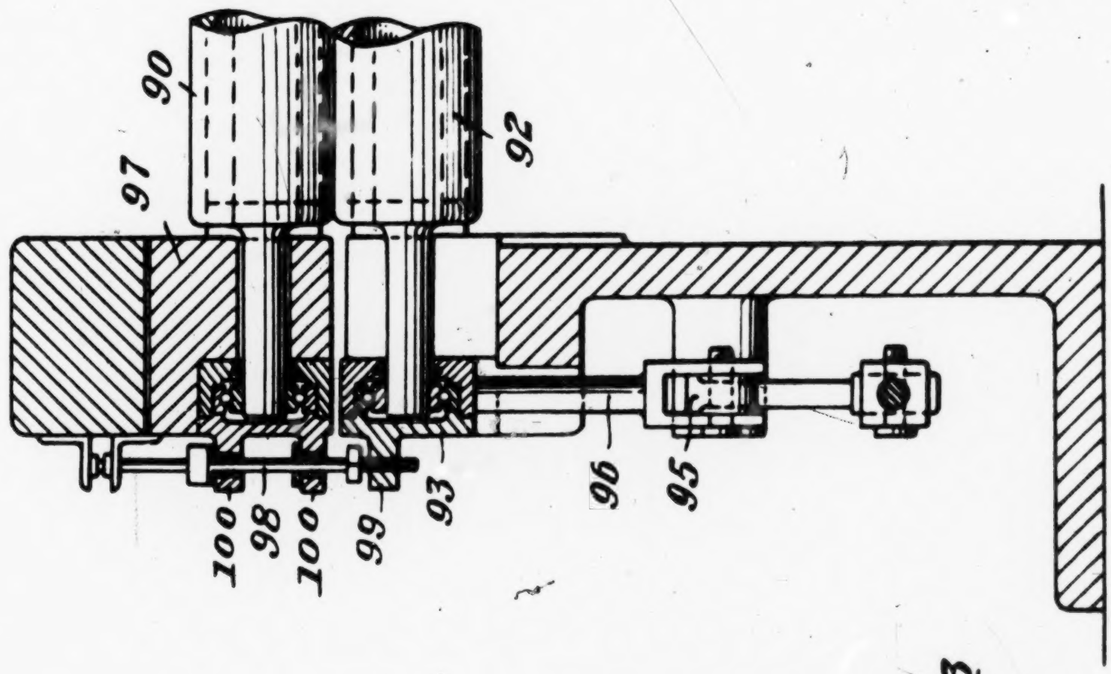
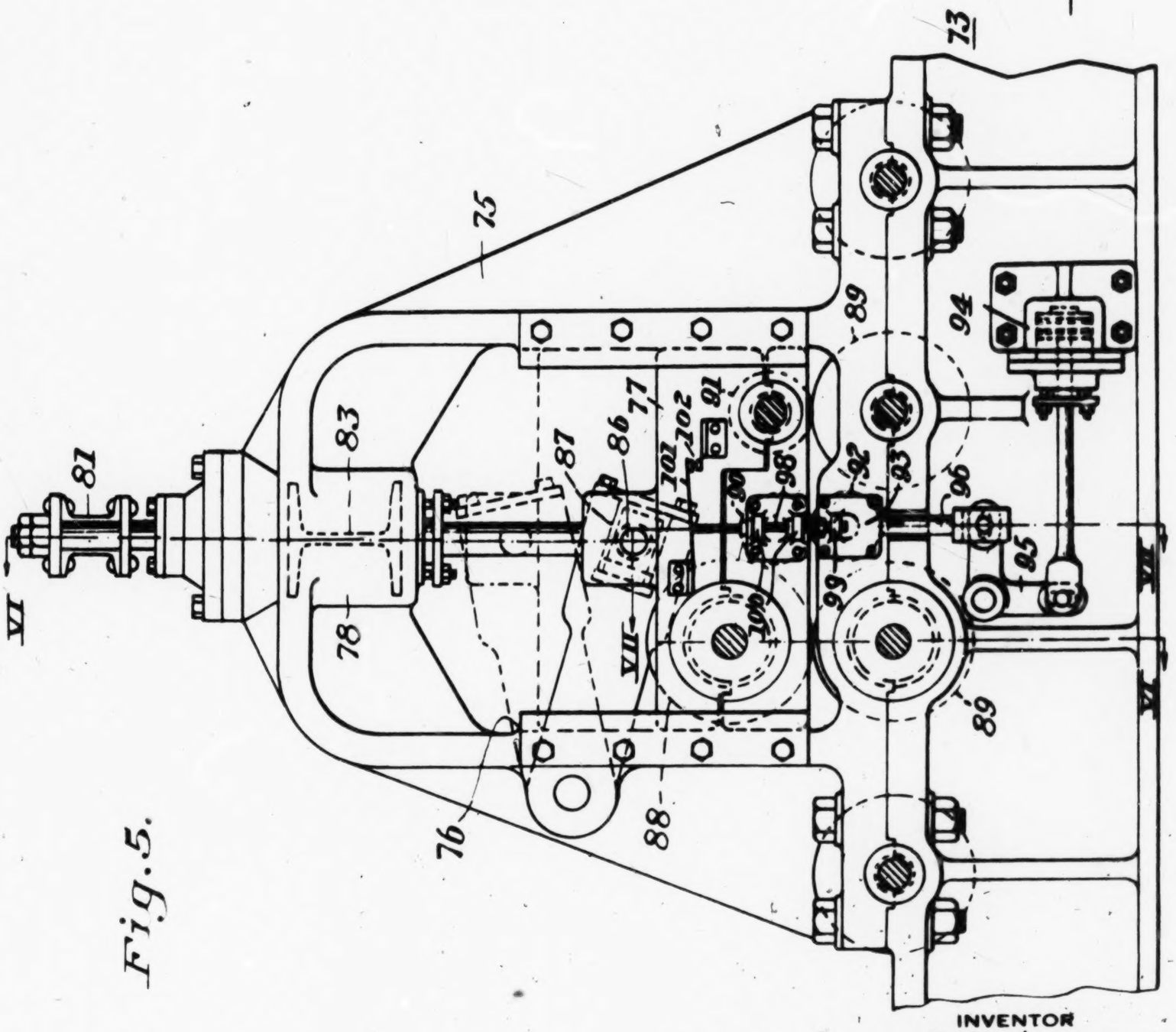


Fig. 5.



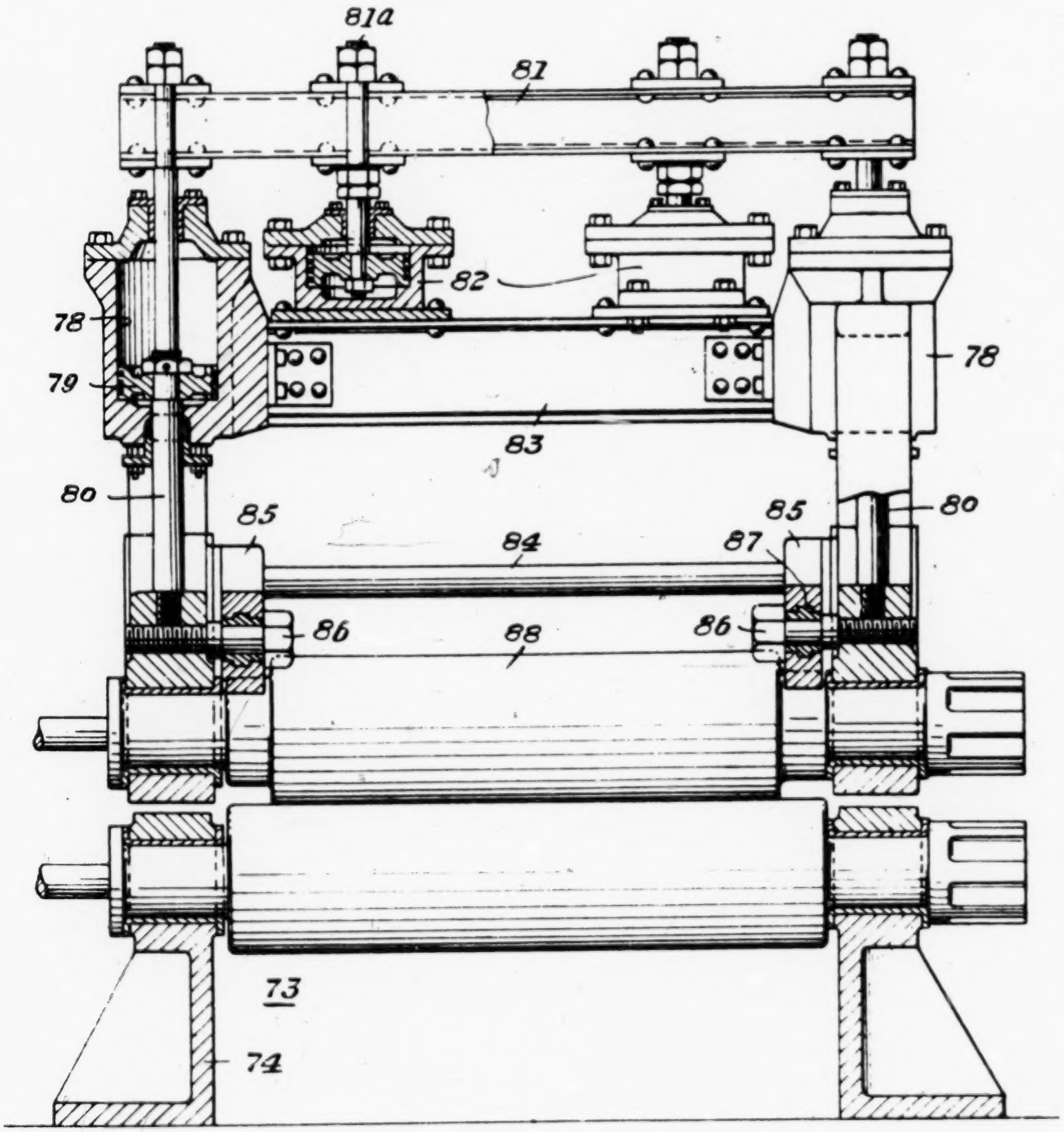
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Fig. 6.



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Fig. 8.

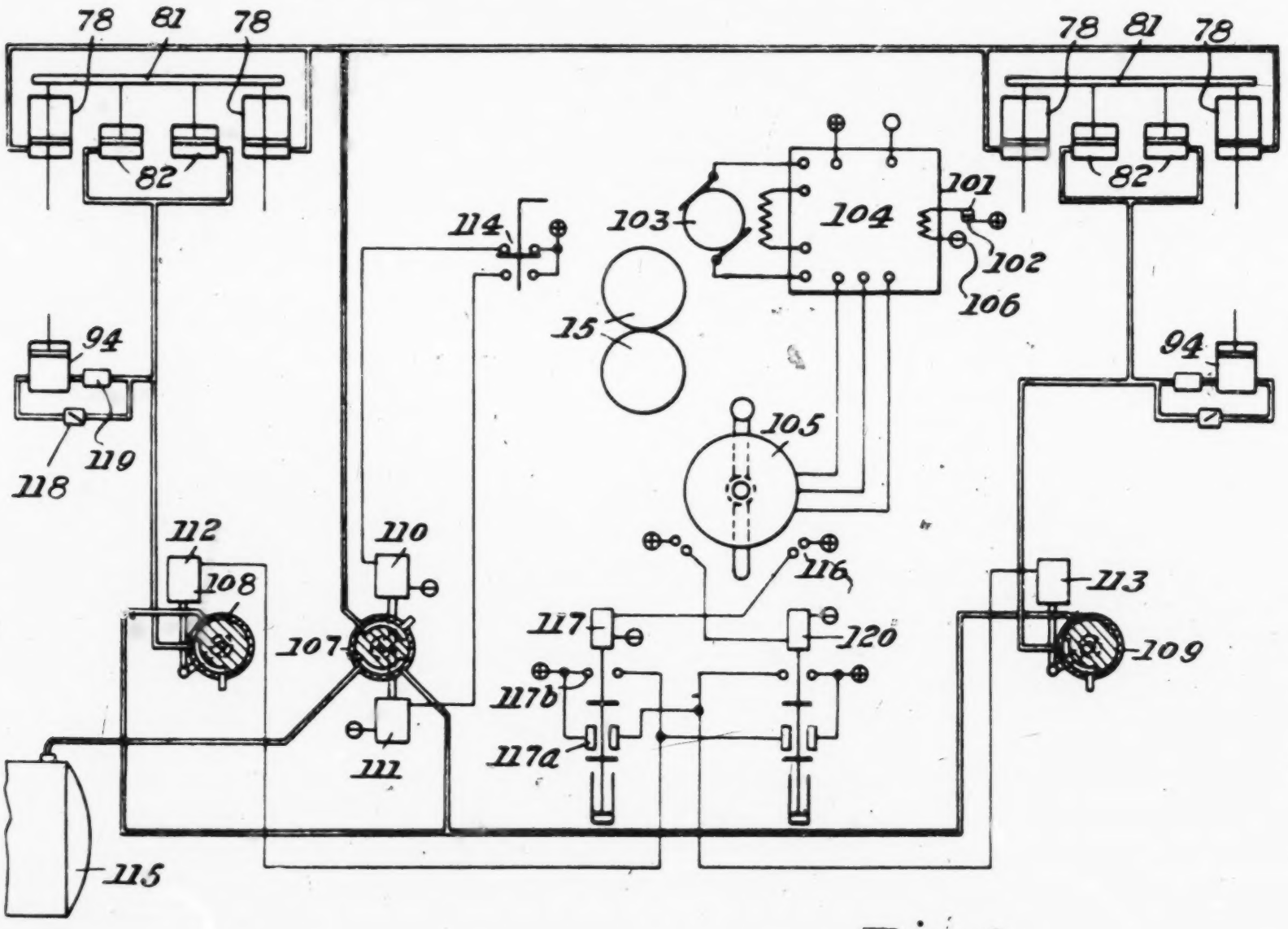
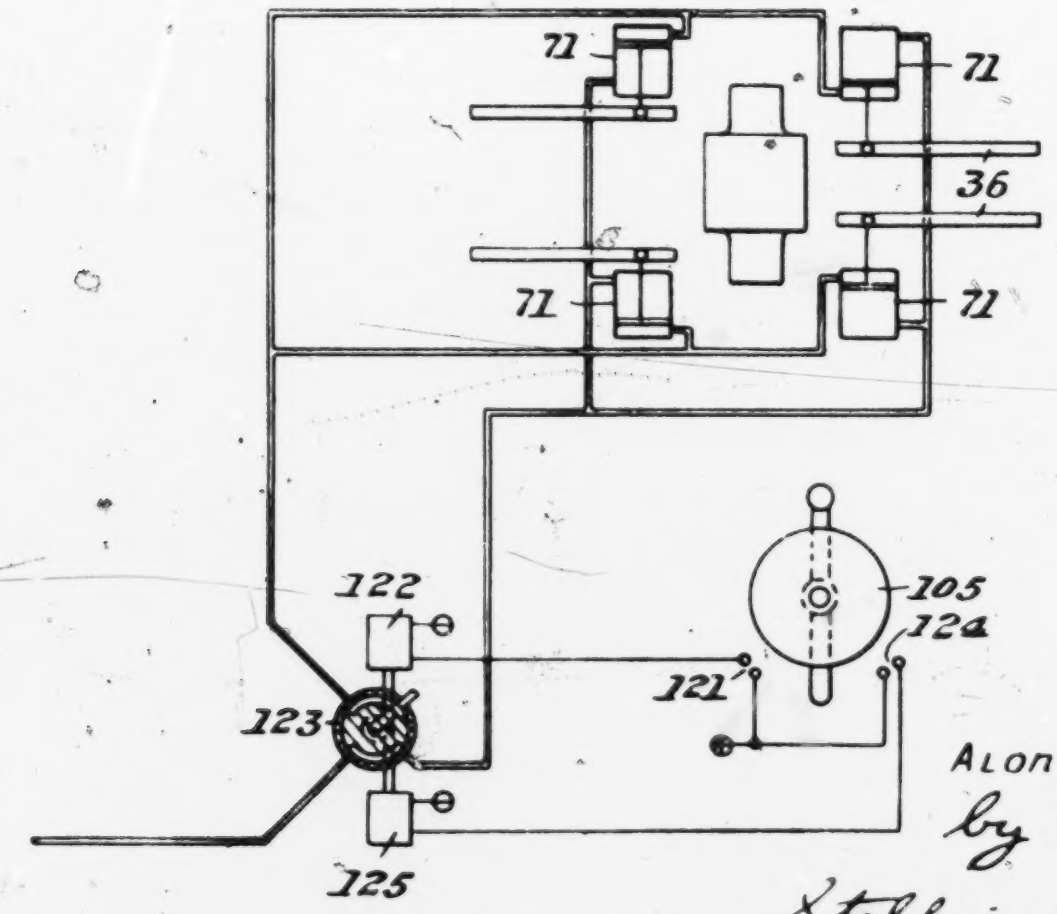


Fig. 9.



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Patented Sept. 10, 1940 2,214,107

UNITED STATES PATENT OFFICE

2,214,107

METHOD OF ROLLING

Jonzo B. Montgomery, Youngstown, Ohio, assignor to The Cold Metal Process Company, Youngstown, Ohio, a corporation of Ohio

Application October 23, 1936, Serial No. 107,193

10 Claims. (Cl. 80—60)

This invention relates to the rolling of metal and particularly to the hot rolling of strip. The hot rolling of strip, by passing a breakdown repeatedly back and forth through a single-stand mill, has been contemplated for many years. It is only recently, however, that any progress has been made in applying this idea in actual practice.

When it was first attempted to roll strip in a single-stand mill with coiling furnaces on both sides thereon, the unwinding reel was retarded to prevent over-running thereof. The principal difficulty with early single-stand strip mills, however, was that they were incapable of consistently rolling a breakdown without camber or longitudinal curvature. This made it necessary to permit the breakdown to coil as it would, loosely, on the winding reel. Because of the looseness of the coil on the winding reel, "skidding" or axial shifting of the turns on the coil being wound up occurred with the result that on the next pass, the back tension imparted to the breakdown by the retarding of the unwinding reel caused one edge or the other to strike the side guides which were employed. This caused the edge of the strip to be folded over into a double thickness.

In my co-pending Patent 2,072,121, for Method and apparatus for guiding material, I have described and claimed a method and apparatus for guiding a slab and the breakdown rolled therefrom so that the latter, when finished, is free from camber. The present invention is useful particularly in conjunction with that of the application aforementioned.

In my copending Patent 2,072,122, I have described and claimed a mill which is an improvement over those of the types shown in United States patents to Keeney et al. No. 1,918,968 and Steckel No. 1,977,214, including guides on both sides of the mill which, while operating on the principle described and claimed in the first mentioned copending application represent a structural improvement over the latter. Beyond the guides, pinch-rolls are disposed and coiling reels are mounted within heating furnaces, in the general manner shown in the patents referred to. In accordance with the present invention, however, I utilize the pinch-rolls only while starting the leading end of a breakdown through the mill and into the coiling reel on the opposite side, the pinch-rolls being thereafter retracted, freeing the strip between the mill and the reel. I then apply sufficient torque to the shaft of the winding reel to tension the portion of the breakdown between the reel and the mill. I also apply a back tension to the portion of the breakdown between the mill and the unwinding reel thereby exerting a retarding torque on the shaft of the latter. By thus tensioning the breakdown, I am able to form a tight coil on the winding reel, thus eliminating "skidding" and preventing cambering of the product during the later rolling passes.

The guides on the exit side of the mill prevent cambering of the leading end of the breakdown until the latter is engaged by the pinch-rolls. The pinch-rolls prevent cambering of the end until the latter is engaged by the coiling reel. With the accurate start thus obtained, correct coiling of the breakdown is assured when the pinch-rolls have been retracted and the guides have ceased to have any effect because of the engagement of the end by the reel. The guides will, however, correct any incipient camber which may appear before the leading end has entered the pinch-rolls. The forward tension, furthermore, will pull out any camber which the mill tends to produce in the breakdown, after the latter has been started on the reel; and the same is true of any camber produced between the pinch-rolls and the reel. So long as the breakdown is free between the mill and coiling reel, it may be controlled by the side guides.

I drive the coiling reel so that at the point where the breakdown enters the reel is moving in a direction opposite that of the strip.

The method of my invention may be best explained by describing a preferred form of the apparatus for carrying it out. This apparatus which is also described and claimed in my Patent 2,072,122, is shown in detail in the accompanying drawings. In the drawings:

Figure 1 is a horizontal section through a mill having my invention incorporated therein showing parts in plan;

Figure 1A is a partial, sectional view similar to Figure 1 showing a slightly modified form of construction;

Figure 2 is a partial side elevation with the mill housings removed for the sake of clearness;

Figure 3 is a partial sectional view along the line III—III of Figure 2, showing parts in elevation;

Figure 4 is a partial, vertical section through the coiling furnace showing other parts in elevation to a slightly enlarged scale;

Figure 5 is a side elevation similar to Figure 4 showing a modified form of construction embodying pinch-rolls particularly adapted for automatic operation, as well as flattening rolls;

Figure 6 is a vertical, sectional view along the

line VI—VI of Figure 5 showing parts in elevation;

Figure 7 is a partial, sectional view along the line VII—VII of Figure 5;

Figure 8 is a schematic diagram of the automatic control system for the apparatus of Figures 5 through 7;

Figure 9 is a similar view of the system for controlling the guides of Figures 1 through 3;

Figure 10 is a diagrammatic plan view of the mill and the driving motors therefor; and

Figure 11 is a side elevation corresponding to Figure 10.

Referring in detail to the drawings, a mill 10 comprises housings 11 having windows 12 for receiving bearing chucks adjustably positioned therein. Backing rolls 14 and working rolls 15 are journaled in the chucks, the rolls preferably having anti-friction bearings, not shown. The housings 11 are connected by transoms 16.

Auxiliary housings 18 are positioned on opposite sides of the mill. Roll tables 19 extend between the housings 18 for conveying material to and from the mill rolls. Furnaces 20 having coilers 21 therein are positioned at a convenient distance from the mill. Tilting guides 22 are provided on the roll tables 19 for diverting material advancing through the mill from a horizontal path of travel into the coilers 21. These coilers are simply spools of convenient size with suitable driving and control equipment, each spool having blades 23 positioned therein, as shown in Figure 4, so that when the leading end of the strip enters one of the coilers between adjacent blades 23, the rotation of the coiler bends the strip around the leading edge of one of the blades. The remainder of the strip is then drawn around a scale-breaking roll 24 at the edge of the furnace mouth and wound up on the coiler.

The rolls 24 are driven by motors 24a (Fig. 10), the direction of rotation of the rolls being such as to aid movement of the breakdown toward the reel. This eliminates any drag on the breakdown which might tend to prevent a positive engagement with the reel. As shown in Fig. 4, the coiling reel is driven in a direction such that the blades on the lower side move in a direction opposite that in which the strip moves.

A base 25 is carried between each of the auxiliary housings 18. Bottom guides 26 are pivotally supported on the bases 25 at 27. The guides 26 are also supported by flat seats 28.

Top guides 29 are pivoted at 30 to the transoms 16 and are suspended from angle bars 31 extending across the mill between the chucks 13 for the top backing rolls, by links 32. The inner ends of the guides 26 and 29 are shaped to conform closely to and are actually in contact with the work rolls to effect a stripping action in case the piece tends to follow around the periphery of one or the other of the rolls.

In the subsequent description of the invention, I shall refer specifically to the equipment on the right-hand side of the mill only, as shown in Figures 1, 2 and 4, but it will be understood that duplicate equipment is employed on the opposite side of the mill.

Screw shafts 33 are slidably mounted in the housing 18 parallel to the axes of the mill rolls. Side guides 34 are supported on the screw shafts 33 by hinged joints 35. The guides 34 have a plane inner surface 36 with recesses into which anti-friction rolls 37 are let. The mill ends of the guides extend to a point closely adjacent the rolls, as shown in Figures 1 and 2. The outer ends of the guides are pivotally supported on nuts 38 traveling on a screw shaft 39 journaled in the side frames of the table 19. The ends of the screw shaft 39 are oppositely threaded so that on rotation of the shaft, the outer ends of the guides are moved toward or away from the center line of the table 19.

From what has been said, it will be apparent that my invention provides side guides which may be disposed in parallel relation, as shown on the left-hand side of the mill in Figure 1, or in angular relation, as shown on the right-hand side of the mill in Figure 1, for the purposes, respectively, of definitely and positively guiding the leading end of an advancing strip into the rolls at the proper angle thereto, and providing a tapering throat for receiving the end of the piece as it emerges from the mill. I shall now describe the mechanism for operating the guide supports to bring about the proper relation of the guides at the proper time.

The outer ends of the guides may be adjusted toward or away from each other through the shaft 39, as already described. This adjustment is effected by a hand wheel 40 having a pinion 41 meshing with a gear 42 along the screw shaft 39. A suitable pedestal bearing 43 is provided for the hand wheel shaft 44. The outer ends of the guides 34 are adjusted manually to the proper spacing before commencing the rolling.

The adjustment of the inner ends of the guides 34 is effected through the screw shafts 33. Gear cases 45 attached to the housings 18 enclose gear wheels 46 having their bores threaded for engagement with the shafts 33, and pinions 47 keyed to shafts 48. Hand wheels 49 permit manual adjustment of the screw shafts 33. These shafts are normally driven from extensions 50 of the shaft of one of the rolls 51 of the table 19. The rolls of the table are driven from a line shaft 52 through the usual bevel gears by a reversing motor, not shown. Between the shaft extensions 50 and the shafts 48 are positioned friction clutches 53 and jaw clutches 54 having operating levers 55. The purpose of the friction clutches is to permit the rotation of the shaft 48 to be arrested after a predetermined movement thereof without stopping the operation of the roll 51. The jaw clutches 54 permit the shafts 33 to be freed from the table drive while being manually adjusted.

The friction clutches 53 have detents 56 thereon cooperating with stops 57 on the housings 18 to limit rotation of the shaft 48 to the desired extent. After the detents engage the stops, the adjustment of the shafts 33 ceases but the roll 51 continues rotating with accompanying slippage of the clutches 53.

It will now be apparent that once the outer ends of the guides 34 have been adjusted, the inner ends of the guides will be spread to form a tapering throat or moved together to parallel position with the reversal of the drive for the rolls of table 19. The detents and stops controlling the amount of rotation of the friction clutches will determine the amount of movement imparted to the inner ends of the guides and may, if desired, be made adjustable. It will be understood, of course, that the guide-operating mechanism is designed so that the guides will be spread at the mill end when the table rolls are driven in such a direction as to move material away from the mill. At the same time, the guides on the opposite side of the mill will be actuated to parallel position. In this way, the material

advancing toward the mill is definitely and positively alined at right angles to the plane containing the axes of the mill rolls. The emerging material is in no wise obstructed but is gently received within a slightly tapering guiding throat. In both cases, the anti-friction rolls 37 prevent binding and insure continuous, steady forward movement of the material without grabbing or slipping. As before stated, the extreme positions of the inner ends of the guides may be adjusted initially by hand after disengaging the clutches 54. Thereafter, the range of movement of the inner ends of the guides is determined by the location of the detents 56 and stops 57. In the construction illustrated, I have assumed that one complete revolution of the shaft 50 will produce the necessary movement of the inner ends of the guides.

Referring now particularly to Figure 4 for a disclosure of the flattening rolls, housings 60 supported on side members of the roll table 19 have bearing chucks 61 movable vertically therein by means of a pneumatic cylinder 62. Rolls 63 and 64 journaled in the chucks 61 cooperate with adjacent rolls 65 of the table 19. A roll 66 also journaled in the chuck 61 cooperates with a roll 67 journaled in adjustable chucks 68. The chucks 68 are actuated by pneumatic cylinders 69.

The rolls 63 and 65 may be driven and when the former is lowered into engagement with the latter, they serve as pinch rolls to feed the strip toward the mill from the coiler 21. When the strip has been started through the mill and engaged the coiler on the opposite side thereof, the chucks 61 are preferably raised and the rolls 63, 64 and 66 lifted off the strip. The chucks 68 of the rolls 67 are preferably lifted at the same time as the chucks 61. In its normal lower position, however, the roll 67 is effective to assist in flattening or leveling the leading end of the material in its passage from the mill to the coiler. The pinch rolls 63 are lowered, of course, at this time. If the leading end, after passing through the pinch rolls, is deflected downward, it will engage the roll 67 and then the roll 65. On passing between the rolls 64 and 65, the end will be flattened sufficiently to engage the coiler 21 without difficulty. Similar results occur if the leading end of the piece is deflected upward, in which case it wil engage the rolls 66 and 64 successively, and after passing between the roll 64 and the roll 65 cooperating therewith, will be found to be satisfactorily flattened. The control of the fluid supplied to the cylinders 62 and 69 has not been illustrated since it may be of any desired character, automatic or manual.

Figure 1A illustrates a modified form of actuating mechanism for the guides 36. This means takes the form of pistons 70 reciprocable in cylinders 71 by means of fluid pressure, hydraulic or pneumatic, supplied thereto. The pistons 70 have piston rods 72 attached thereto corresponding to the screw shafts 33 and functioning in the same way, under the influence of fluid pressure admitted to either side of the cylinders 71 for actuating the guides.

A modified form of construction of the auxiliary rolls for feeding and flattening the strip is shown in Figures 5 through 7. A roll table 73 has side frame castings 74. Housings 75 are attached to the castings 74 and have windows 76 therein in which bearing chucks 77 are slidable. Cylinders 78 formed in the upper part of the housings 75 have pistons 79 reciprocating therein. Piston rods 80 attached to the pistons 79 are threaded into the chucks 77 whereby the latter may be lifted to the dotted line position shown in Figure 5. Piston rods 80 extend outwardly through the upper end of the cylinders 78 and are connected by cross beams 81. Cylinders 82 carried on a transom 83 extending between the housings, also have pistons and piston rods arranged as shown in Figure 6 whereby the beams 81 and, therefore, the chucks 77, may be raised through a small distance. The piston rods of the cylinders 82 have separable, abutting engagement with bolts 81*a*. It will be apparent that the cylinders 78 and 82 provide independent means for lifting the chucks 77 through a long stroke and a short stroke, respectively. The object of this arrangement will become apparent as the description proceeds.

An equalizing shaft 84 extends between the housings 75 and is journaled therein. Cranks 85 keyed to the shaft 84 carry trunnions 86 in slidable bearing blocks 87. The trunnions 86 are threaded into the chucks 77, as best shown in Figure 6. The equalizing shaft obviously serves to effect simultaneous and equal movement of both bearing chucks and prevents binding of the reciprocating mechanism.

A top pinch roll 88 is journaled in the chucks 77 for cooperation with a bottom pinch roll 89, which may conveniently be one of the rollers of the table 73. Flattening rolls 90 and 91 are also journaled in the chucks 77. The roll 91 cooperates with a roll of the table 73. A roll 92 is journalled in chucks 93 slidable vertically in the base portions of the housings 75. Cylinders and pistons 94, bell crank linkage 95 and struts 96 are provided, as shown in Figure 5 to effect vertical movement of the chucks 93 for a purpose which will appear later.

As best shown in Figure 7, the roll 90 is journaled in chucks 97 secured to the chucks 77. A contact-actuating rod 98 is threaded into a projection 99 from one of the chucks 93. The rod 98 also passes through guides 100 projecting from one of the chucks 97. The rod 98 controls the engagement of a moving contact 101 with a fixed contact 102 on one of the chucks 77 for a purpose which will presently appear.

The chucks 93 are normally lowered so that contact 101 engages contact 102. These contacts control a circuit for stopping the main mill motor in case of breakage of the strip. When the strip is being rolled, the rolls 88, 90 and 91 rest on the strip and are spaced thereby from the rolls 89 and 92. After the strip has been entered into the mill so as to separate the pinch rolls 88 and 89, fluid is admitted to the cylinders 94 to cause the chucks 93 to be raised until the roll 92 engages the lower surface of the strip. The rolling operation then proceeds. If breakage of the strip should occur, the continuing fluid pressure in the cylinders 94 causes the chucks 93 to rise until the roll 92 actually engages the roll 90. This causes the rod 98 to move upwardly and lift contact 101 out of engagement with contact 102. Separation of these contacts, through suitable auxiliary equipment, causes stoppage of the main mill motor.

The cylinders 79 and 82 are automatically controlled to cause the pinch rolls 88 and 89 to engage the material at certain times and to release it at other times.

In rolling a slab into strip on the mill 10, it is desirable that the pinch rolls 88 be withdrawn as long as the slab being reduced has sufficient rigidity to permit it to be fed back and forth to

and from the mill by the friction of the table rolls. When the slab has been reduced to a gauge such that it has relatively little rigidity, or to a condition in which coiling between passes is advisable, the pinch rolls are advanced to assist in threading the strip through the mill at the beginning of each pass. While both ends of the strip actually pass through the mill, the pinch roll motors are so controlled that neither end of the strip is disengaged from the pinch rolls on both sides of the mill. At least one end of the strip is always engaged by at least one set of pinch rolls. It is by these pinch rolls that the strip is then fed back to the mill for the next pass. On the exit side of the mill, the pinch rolls assist in delivering the leading end of the strip into the coiler by pushing it up the guide 22.

The system for automatically controlling the pinch rolls will be now explained with reference to Figure 8. In Figure 8, the work rolls of the mill are indicated by the same numeral as in Figures 1 and 2. A motor 103 is provided for driving the mill and the power of the motor may be applied directly to the work rolls 15 or to the backing rolls 14. The motor 103 may be controlled by any suitable control system. For simplicity, I have only illustrated a control panel 104 having incoming power leads, outgoing motor leads, and outgoing control leads extending to a controller 105. The panel 104, of course, will be provided with suitable relays and contactors effective under the control of the controller 105 to cause starting of the motor 103. The panel 104 also has a relay 106 effective when deenergized to cause stopping of the motor. The specific details of such an arrangement are known and need not be included here. The controller 105, obviously, is effective on being shifted manually in one direction or the other, to cause operation of the motor 103 to drive the mill rolls 15 and thus move the strip through the mill in the desired direction. The supply of fluid to the cylinders 78, 82 and 94 is controlled by a master valve 107 and auxiliary valves 108 and 109. The valve 107 has operating magnets 110 and 111 and the valve is of such character that it remains in the position to which it was last operated until positively actuated therefrom. The valves 108 and 109 have operating magnets 112 and 113. The arrangement of these valves and their operating magnets is such that they remain in the illustrated position until the magnets are energized, and return to the illustrated position when the magnets are deenergized.

The valve 107 is controlled by a limit switch 114 operated by any convenient means, in accordance with the position of the mill screwdowns which determine the thickness of the pass between the rolls and the material itself after passing through the mill. When the space between the mill rolls 15 is greater than a predetermined value, say ¾", the limit switch 114 closes its lower contacts to energize the magnet 111 and move the valve 107 so that fluid under pressure is supplied from a reservoir 115 through suitable piping, to the cylinders 78 on both sides of the mill. The pistons 79 are thereby actuated full stroke to withdraw the upper pinch roll 88 and provide ample free space for the passage back and forth to and from the mill of the slab in the initial stages of its reduction to strip.

When the thickness of the slab has been reduced to a point such that, on the next pass, the mill rolls are spaced apart only ¾" or less, the partially reduced material is sufficiently thinned and elongated to permit of coiling and, at the same time, its rigidity is such that the assistance of the pinch rolls is required to manipulate it through the mill and into the coilers. The limit switch 114 then closes its upper contacts to energize the magnet 110 and operate the valve 107 to the illustrated position. This vents the cylinder 78 and the pistons 79 immediately drop to lower the pinch rolls 88 onto the material. The pinch rolls are driven by any convenient means, at the same peripheral speed as the rolls 15, so as to cooperate therewith in moving the material back and forth.

If it is assumed for the sake of explanation that the breakdown formed from flat rolling the slab was reduced on a pass from left to right, to a gauge such that after the next reduction, it would be less than ¾" thick, as soon as the top roll 15 is lowered to within less than ¾" of the bottom roll, the described operation of the valve 107 will take place and the pinch rolls will seize the breakdown for the next pass from right to left. When all is ready for this pass, the roller operates the handle of the controller 105 to the left, as shown in Figure 8, whereupon the motor 103 is operated so as to drive the rolls 15 and roll the strip from right to left. The pinch roll drive is so coordinated with that of the mill that the pinch rolls 88 are simultaneously operated so as to assist in the feeding of the breakdown.

The movement of the controller 105 bridges contacts 116 to energize a relay 117. The relay 117 has a time delay in its operation, indicated by a dashpot, and after a certain time bridges contacts 117*a* to energize the magnet 113. The relay is adjusted so that the contacts 117*a* will be bridged just after the leading end of the breakdown being rolled passes between the rolls 15. The magnet 113 operates the valve 109 to admit fluid supplied through the valve 107 to the cylinders 82 on the entering side of the mill. The pinch roll 88 on that side is thus lifted from the material.

After a slightly longer time, the relay 117 operates to bridge its contacts 117*b*, maintaining the circuit for the magnet 113 by reason of the fact that the bridging contact slides along the contacts 117*a*. The relay is adjusted so that the contacts 117*b* are bridged after the material has emerged from the mill on the exit side, passed through the pinch rolls, and made one turn about the coiler. The bridging of the contacts 117*b* causes the operation of magnet 112 to shift the valve 108. The cylinders 82 on the exit side of the mill thus operate to raise the associated pinch roll from the strip. The strip is thus free between the winding and unwinding coilers, except where engaged by the mill.

The operation of the valves 109 and 108 described above, also causes the operation of the cylinders 94 on opposite sides of the mill. The roll 92 is thus raised into engagement with the material but is sufficiently spaced thereby from the roll 90 that the contact 101 remains in engagement with the contact 102. The fluid pressure is continuously applied to the cylinders 94 as long as the rolling continues but, unless the strip breaks during rolling, the rolls 90 and 92 are maintained separated and the contacts 101 and 102 remain in engagement. If the strip is broken, the roll 92 is immediately lifted into engagement with the roll 90, whereupon the rod 98

lifts the contact 101 to open the circuit for the relay 106 and thereby stop the motor 103.

As soon as the leading end of the breakdown has been engaged by the coiling reel, and the pinch rolls retracted, I cause the motor 21a driving the coiling reel to exert thereon a torque sufficient to impart tension to the breakdown between the coiling reel and the mill. At the same time, I operate the motor 21a connected to the unwinding reel as a generator, to impart a back tension to the portion of the breakdown between the uncoiling reel and the mill. The torques exerted by the motor and generator are preferably maintained constant by any convenient means such as current regulators effective to maintain constant currents through the armatures of the motor and generator. The relationship of the regulators to the motor and generator is reversed on reversal of the mill, the regulator for the coiling-reel motor, obviously, being set for a greater current than the regulator connected to the uncoiling-reel generator.

By this provision, I tension the breakdown on the exit side of the mill between the mill and coiling-reel. On the entrance side, the breakdown is tensioned between the mill and the uncoiling-reel.

When the pass is completed, the controller 105 is restored to neutral position so that the trailing end of the strip stops between the mill and the pinch rolls on the exit side thereof. The relay 117 is thus deenergized and substantially immediately opens its contacts to deenergize magnets 112 and 113. The cylinders 82 are thus exhausted to the atmosphere and the pinch rolls dropped. At the same time, the cylinders 94 are exhausted through check valves 118, the weight of the roll 92 and chucks 93 serving to force the accumulated fluid out of the cylinders. The operating fluid for the cylinders 94 passes initially through expansion valves 119 which slightly delays the lifting of the chucks 93 on starting a pass.

The next pass is accomplished in exactly the same manner. Reversal of the controller 105 energizes the relay 120 and this, in turn, causes sequential lifting of the pinch rolls 88 on the entering and exit sides of the mill. This cycle is repeated until the strip has been reduced to the desired gauge, when it is wound on a coiler beyond the furnace on the exit side of the mill. The top work roll is then lifted by reversal of the screwdowns. The switch 114 closes its lower contacts and operates the valve 107 to admit fluid under pressure again to the cylinders 78, whereby the pinch rolls 88 on both sides of the mill are lifted out of the way for the next flat rolling operation.

Figure 9 shows how the side guide actuators of Figure 1A are controlled. When the controller 105 is shifted so as to cause the material to be fed from left to right, it closes contacts 121. It will be understood that operation of the controller also, through appropriate relays, causes the starting of the motor 103 in the proper direction. The closing of the contacts 121 energizes an operating magnet 122 for a valve 123. This valve is similar to that shown at 107 of Figure 8. The energization of the magnet 122 operates the valve to the position illustrated in Figure 9, in which it delivers fluid under pressure to the inner ends of the cylinders 71 on the exit (left-hand) side of the mill, and to the outer ends of the cylinders on the entering (right-hand) side of the mill. The guides 36 on the entering side are thus closed in, as indicated in Figure 9, while the guides on the exit side are opened to permit free passage of the material as it emerges from the mill.

On the reversal of the direction of rolling, for the next pass, the controller 105 bridges contacts 124 and energizes a magnet 125 to shift the valve 123 to the other position. The reverse operation of the cylinder 71 then takes place to close the guides on the left-hand side and open the guides on the right-hand side.

It will be understood that only a single controller 105 is employed and that it controls contacts 116 and 124, for example, simultaneously, in addition to the other contacts necessary to bring the motor 103 up to operating speed. The system of Figure 9 is shown separately from that of Figure 8 simply because it is a diagrammatic plan, whereas the latter is a diagrammatic elevation, but it will be understood that the two systems are combined and under the common control of the controller 105.

It will be apparent from the foregoing description that my invention provides a rolling mill having numerous advantages over known apparatus of the same kind. In the first place, the slab or strip is definitely guided into the mill along the pass line or longitudinal axis of the mill. There is thus no possibility for the strip to move into the rolls crabwise at a slight angle to the pass line. Cambering of the strip or slab is thus prevented. Free movement of the highly flexible, thin strip from the mill is permitted without obstruction since the guides on the exit side of the mill are automatically retracted to form a tapering guiding throat. The positions of the guides on opposite sides of the mill are reversed automatically with the reversal of the roll tables and the mill so that once the guides have been adjusted, they require no further attention until a different width of material has to be rolled.

The flattening rolls insure that the leading end of the strip will always be sufficiently flat to enter and engage the coiler properly to wind the strip thereon. This avoids the delays experienced heretofore incident to the backing up of the strip and repeating the entry thereof into the coiler after a first unsuccessful attempt.

The top and bottom guides 29 and 26 respectively, with the side guides 34, form a complete guide box and prevent any departure of the strip from the pass level or the horizontal plane through the roll pass. With the guides of my invention, improper entry of the material into the mill is rendered almost impossible. The top guide may be adjusted by a turn-buckle in the links 32. The bottom guide may be similarly adjusted by shimming up the outer end thereof which rests on the seat 28.

The automatic control of the pinch rolls on both sides of the mill insures that the strip will be advanced properly into the mill and, on emerging therefrom, into the coiler, whereupon the pinch rolls will be lifted out of the way when there is no further need for them. The automatic stop mechanism prevents loss, damage or injury in case the strip breaks during a pass.

The positive actuation of the side guides under the control of the main controller causes the strip to be properly started toward the mill and correctly positioned with respect thereto before it actually enters between the mill rolls, after which no effort is sufficient to correct an improper starting of the strip, because of the great force exerted on the strip by the rolls.

The top guide 29 has an important function in

preventing the coiling up of the leading end of the piece when rolling in the flat. If it were not for this guide, the slab, in the early stages of its reduction, might bend up sufficiently to escape the side guides altogether, whereupon it might be improperly entered into the mill pass on the next reversal.

By tensioning the portion of the breakdown between the mill and the coiling reel, I cause the material to coil tightly and accurately on the coiling reel, thus avoiding skidding and possible deformation of the edge of the breakdown on the next pass. The tension also serves to remove any camber which might be rolled into the strip by the mill. By raising the pinch rolls after starting the piece through the mill, I avoid introducing camber into the material as a result of the reduction caused by the pinch rolls. The guides serve to correct camber of the leading end of the piece while it is free. The pinch rolls tend to prevent the introduction of the camber before the piece is started on the reel. Thereafter, the forward tension prevents cambering at a time when the guides are comparatively ineffective. If the material departs from the center line of the mill while the pinch rolls engage it, this departure will be corrected as soon as the pinch rolls are raised and forward tension is applied.

By driving the coiling reel in a direction such that the point where it is engaged by the leading end of the breakdown is traveling in a direction opposite that of the latter; I ensure positive engagement by hooking the end of the piece around the leading edge of one of the reel plates.

Although I have illustrated and described only one embodiment of my invention, it will be apparent that numerous changes therein may be made without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. In a method of hot rolling a breakdown into strip by passing it back and forth through a mill having pinch rolls on both sides thereof and coiling reels beyond the pinch rolls, the steps including causing the pinch rolls on one side of the mill to engage the trailing end of a breakdown coiled on the reel on that side of the mill, driving last mentioned pinch rolls to feed said end back to the mill, driving the pinch rolls on the other side while maintaining them in gripping engagement with the breakdown to feed said end toward the other reel, and retracting at least one of each set of pinch rolls to free the breakdown between the mill and the reels during the remainder of the pass.

2. The method defined by claim 1 characterized by so driving the winding reel as to tension that portion of the breakdown between it and the mill.

3. The method defined by claim 1 characterized by so retarding the unwinding reel as to tension that portion of the breakdown between it and the mill.

4. In a method of converting a slab or ingot into strip, the steps including passing a slab back and forth in the flat between reducing rolls to form a breakdown, passing the breakdown back and forth between reducing rolls to form a strip, winding the breakdown on a coiling reel between passes through the rolls, bending the breakdown about a guide roll, and driving said guide roll to prevent frictional drag on the breakdown.

5. The method defined by claim 1 characterized by retracting one of each set of pinch rolls a greater distance before starting the rolling of a breakdown into a strip, while rolling the breakdown from a slab or ingot without coiling.

6. In a method of rolling strip, the steps including passing a breakdown, heated to plastic condition, back and forth between reducing rolls, uncoiling it on one side and coiling it on the opposite side of the rolls, passing an end of the breakdown entirely through the rolls, frictionally gripping said end to feed it back through the rolls, freeing that portion of the breakdown between the mill and the point of coiling, and tensioning such portion uniformly throughout.

7. In a method of making strip by passing a breakdown, heated to plastic condition, through reducing rolls, coiling the strip on the exit side, uncoiling it from a previously formed coil on the entrance side of the rolls, gripping the strip at points between the rolls and points of coiling only long enough at the beginning of each pass to thread the end of the breakdown through the rolls and start coiling thereof on the exit side, and then freeing the breakdown between the rolls and the points of coiling, while continuing to pass the strip through the mill in the same direction.

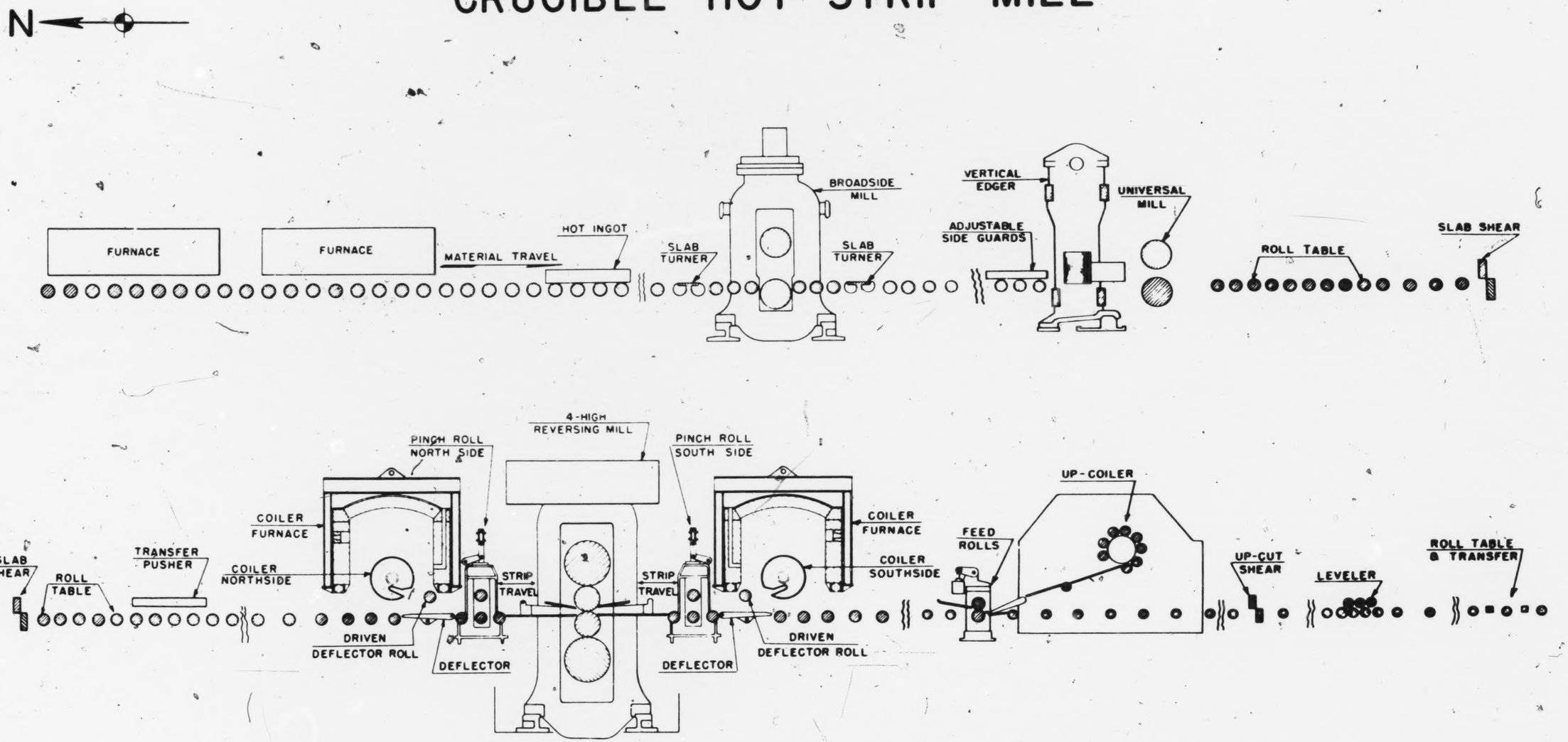
8. The method defined by claim 7 characterized by tensioning the portion of the breakdown between the rolls and the point of coiling uniformly throughout to cause the breakdown to coil straight and true.

9. In a method of rolling strip, the steps including passing a breakdown back and forth between reducing rolls, coiling the breakdown on one side of the mill between passes, frictionally engaging the outer end of the coil to drive it back toward the mill between parallel edge guides, receiving said end as it emerges from the mill between converging edge guides, frictionally engaging said end to drive it toward the point of coiling on the exit side of the mill, and freeing the portions of the breakdown inwardly of the edges thereof and between the mill and the points of coiling from frictional driving or retarding engagement.

10. The method defined by claim 9 characterized by coiling the breakdown emerging from the mill under torque sufficient to tension uniformly that portion of the breakdown between the mill and point of coiling to cause it to wrap true in a coil.

ALONZO B. MONTGOMERY.

CRUCIBLE HOT STRIP MILL



DIAGRAMMATIC SECTION OF COMPLETE MILL

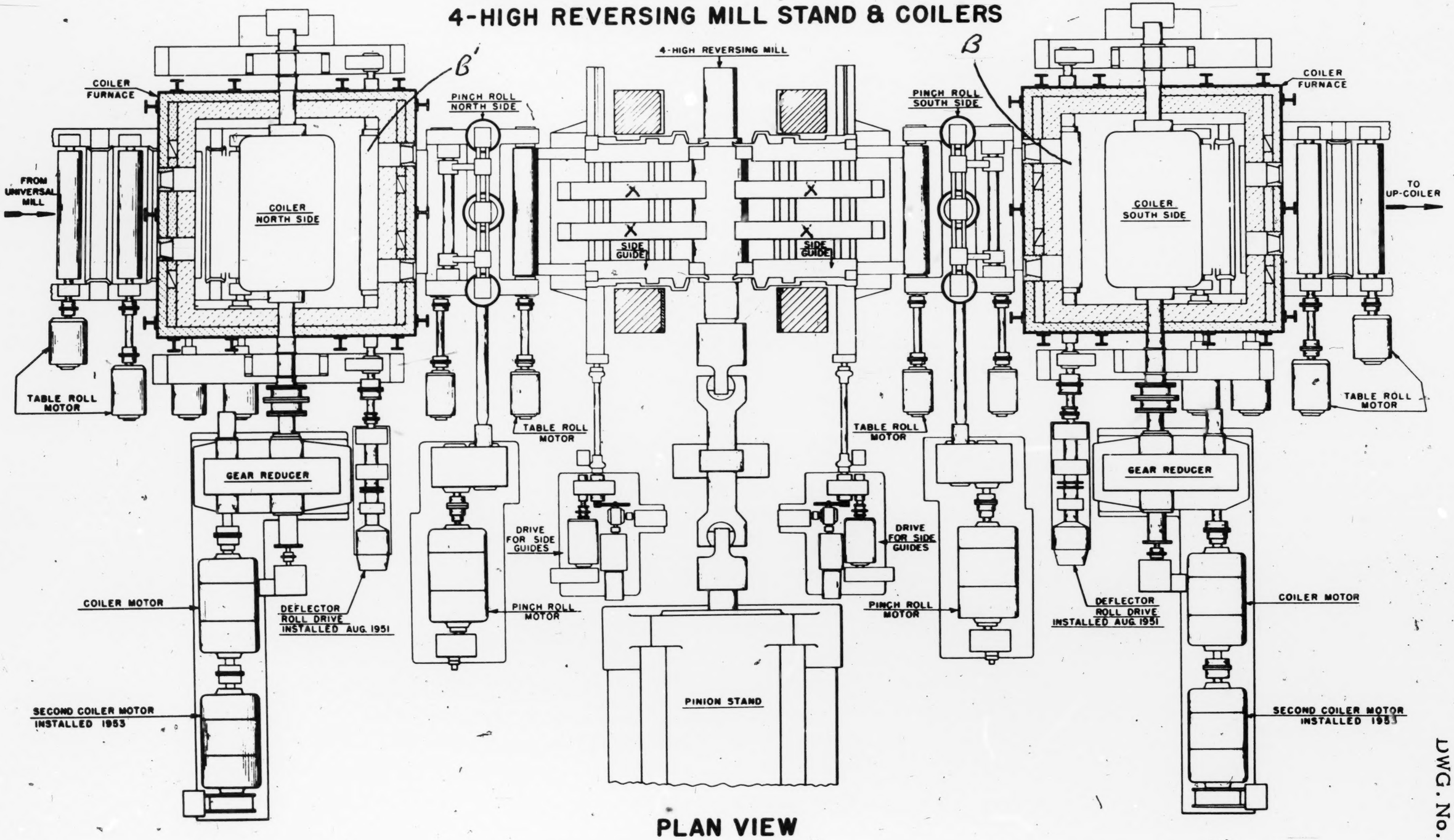
Plaintiff's Exhibit P-16.

131a

DWG. No. 1

CRUCIBLE HOT STRIP MILL

4-HIGH REVERSING MILL STAND & COILERS

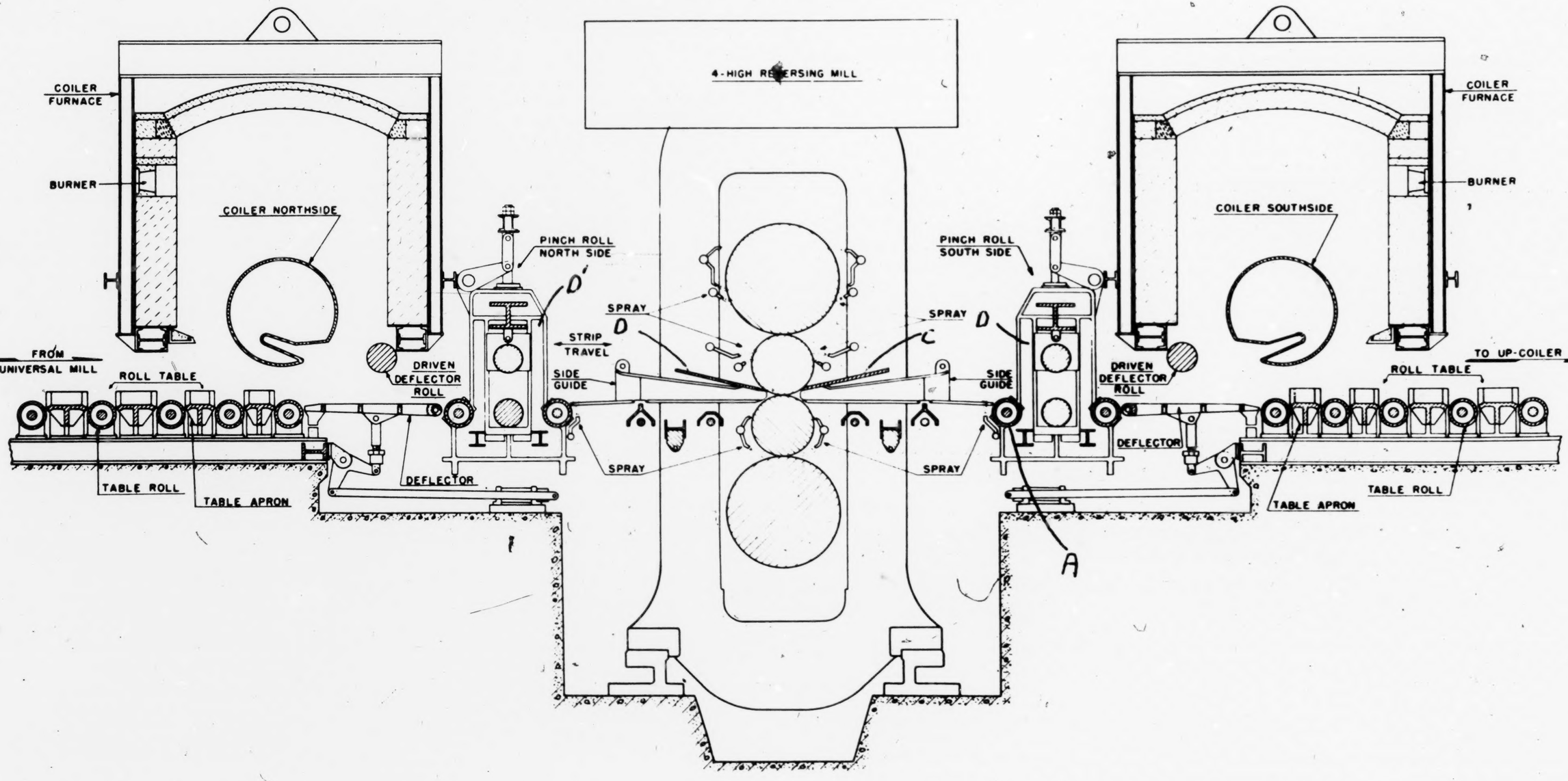


PLAN VIEW

133a
DWG. No. 2

CRUCIBLE HOT STRIP MILL

4-HIGH REVERSING MILL STAND & COILERS

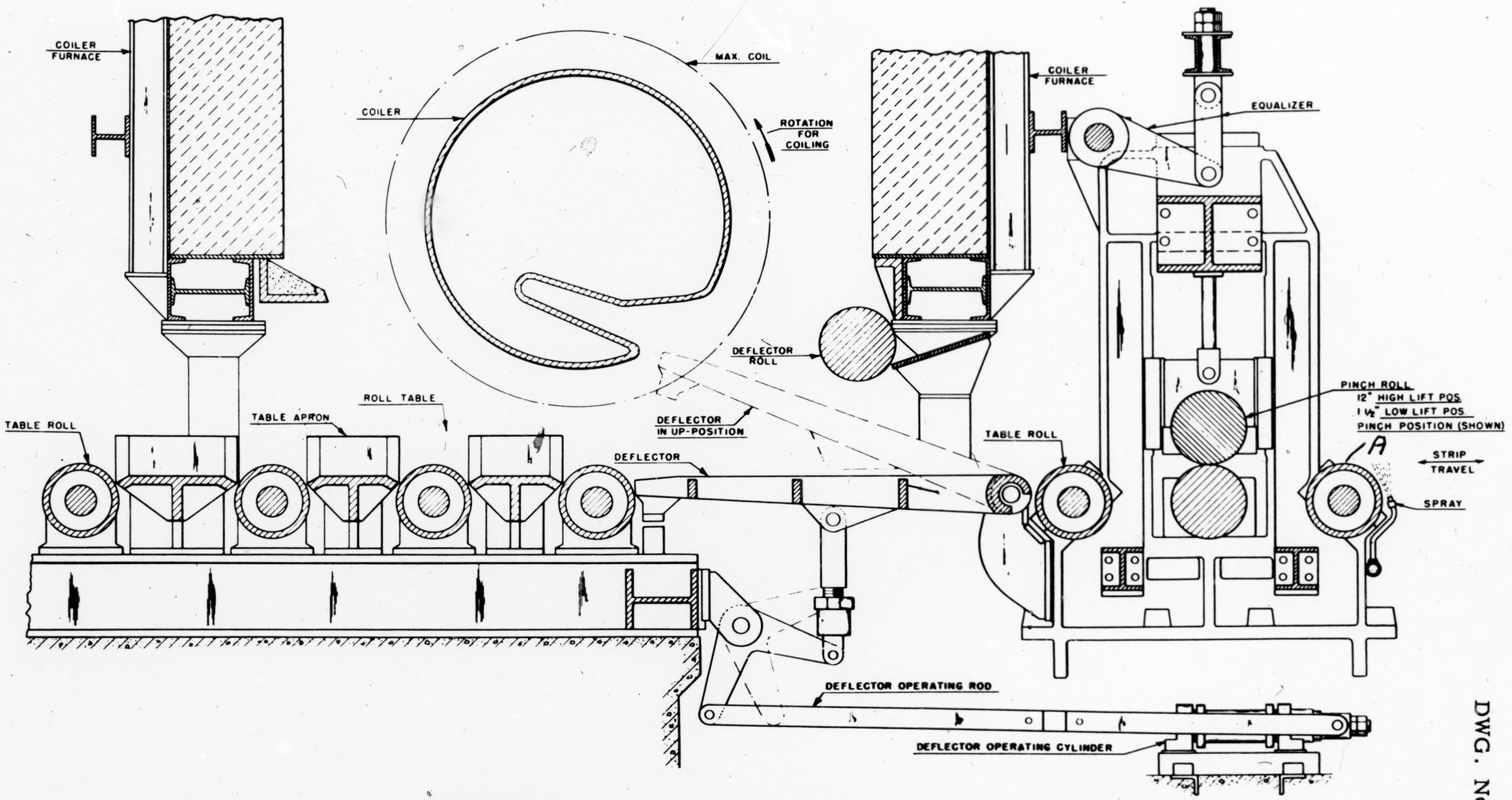


VERTICAL SECTION

DWG. No. 3

135a

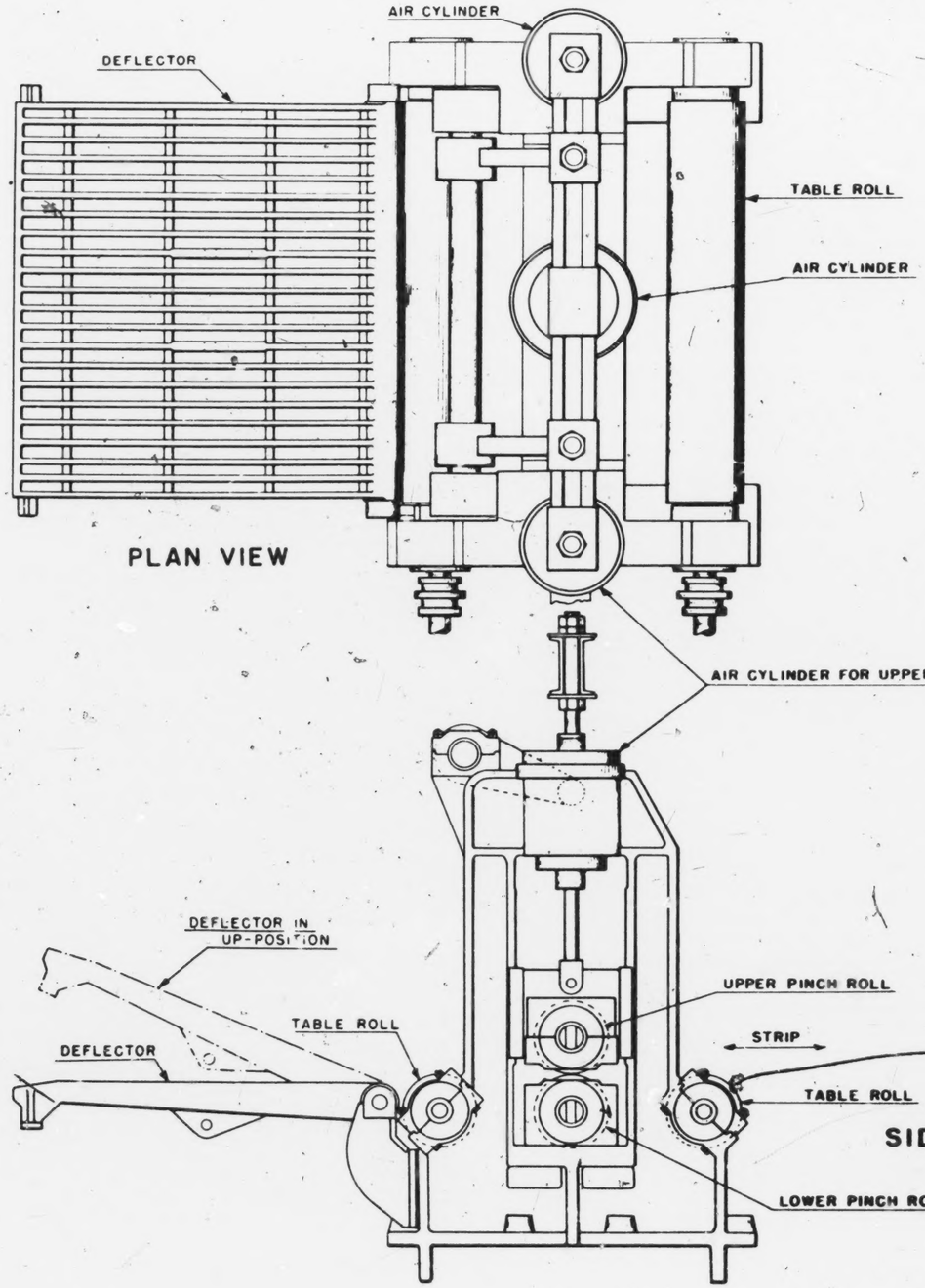
CRUCIBLE HOT STRIP MILL



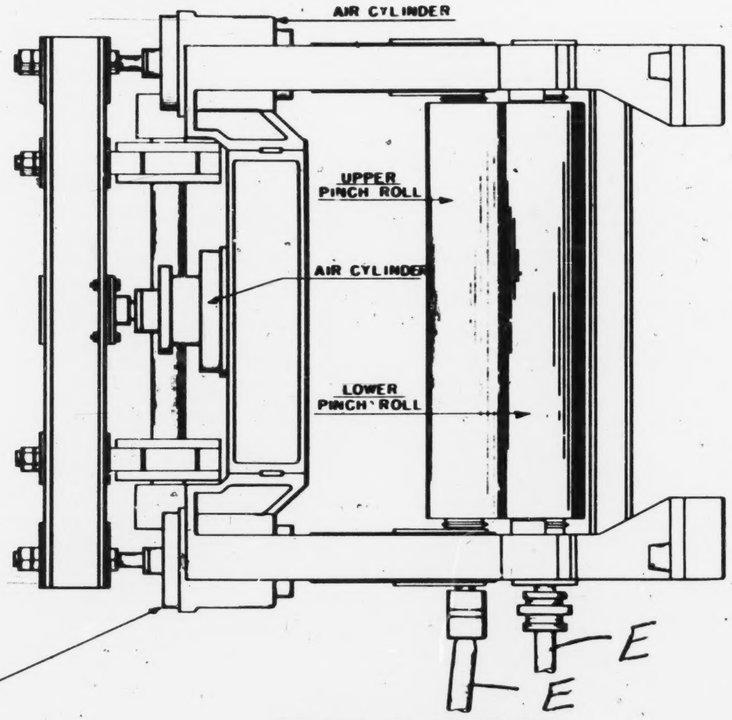
VERTICAL SECTION AT PINCH ROLL & COILER

DWG. No. 4

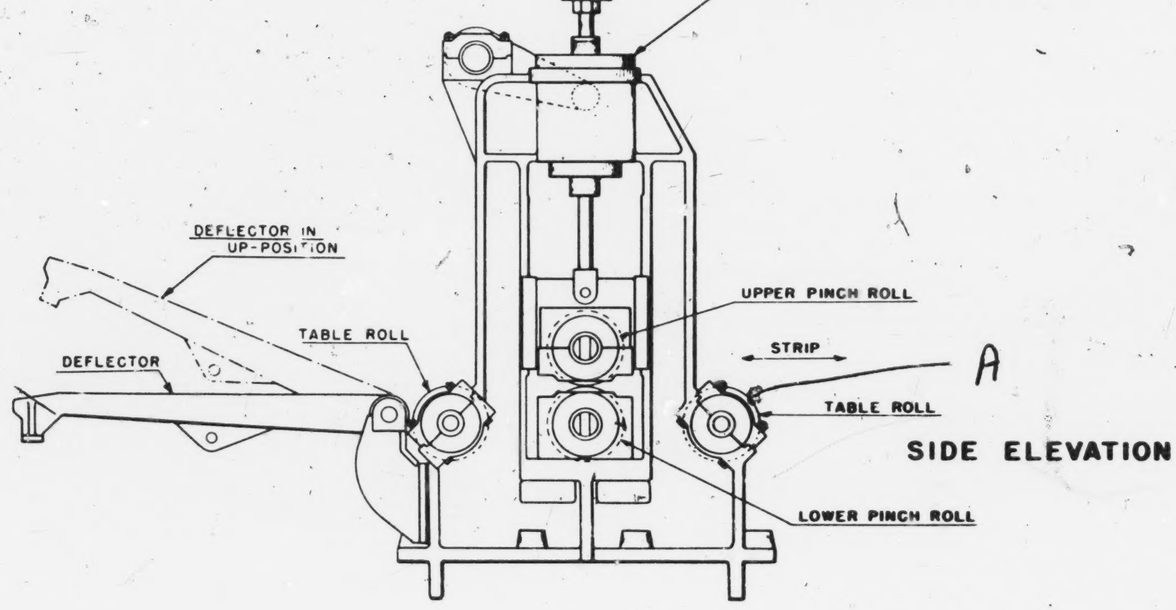
CRUCIBLE HOT STRIP MILL



PLAN VIEW



FRONT ELEVATION



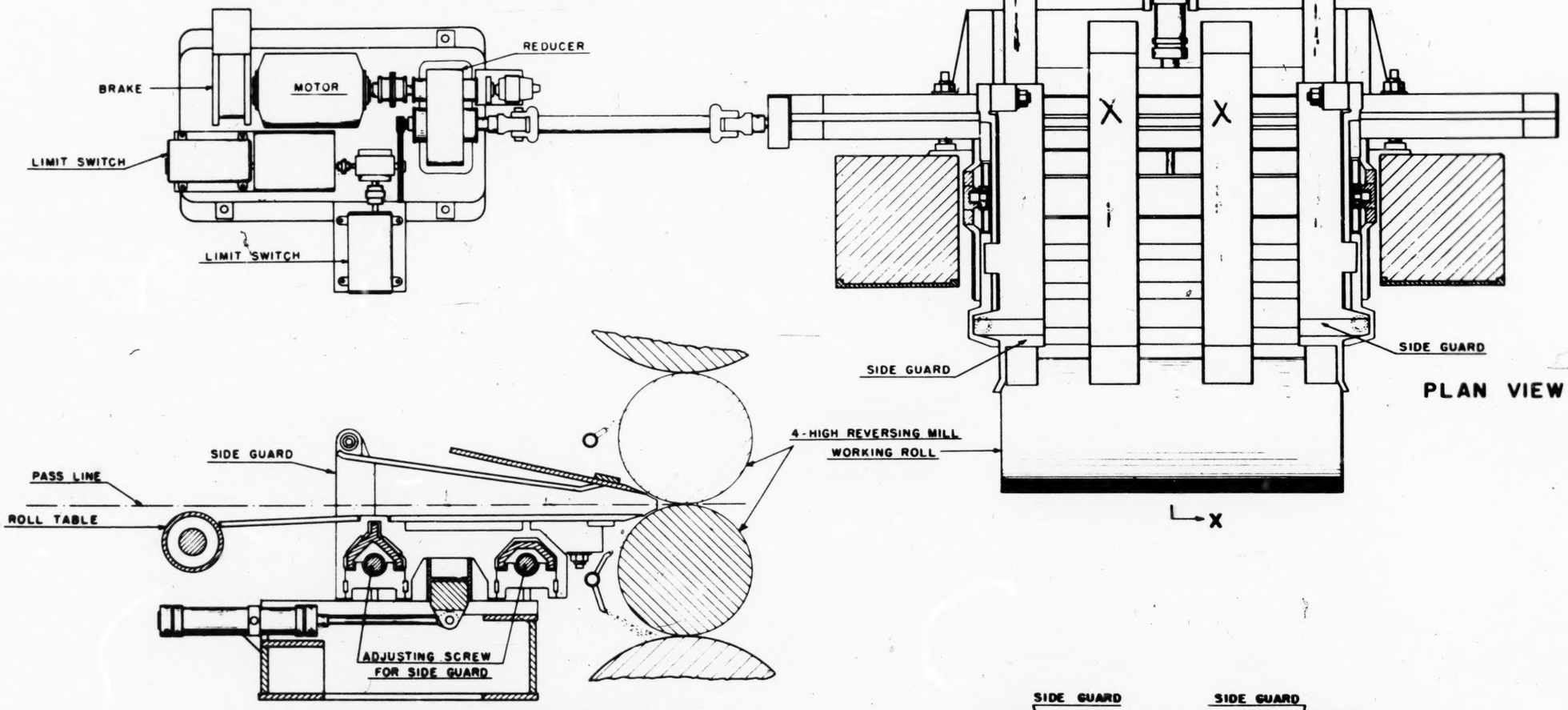
SIDE ELEVATION

DEFLECTOR AND PINCH ROLL ASSEMBLY

139a.
DWG. No. 5

CRUCIBLE HOT STRIP MILL

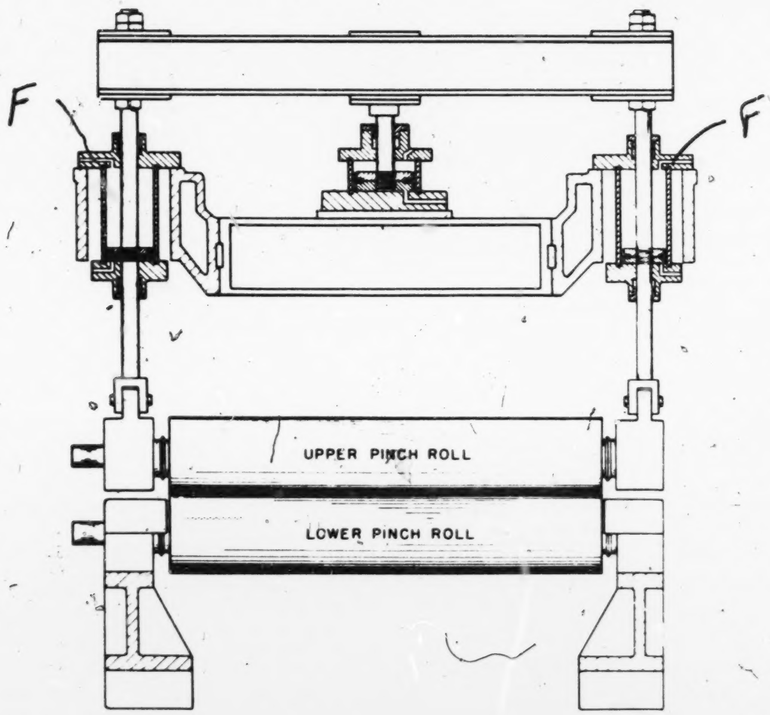
SIDE GUIDE ASSEMBLY



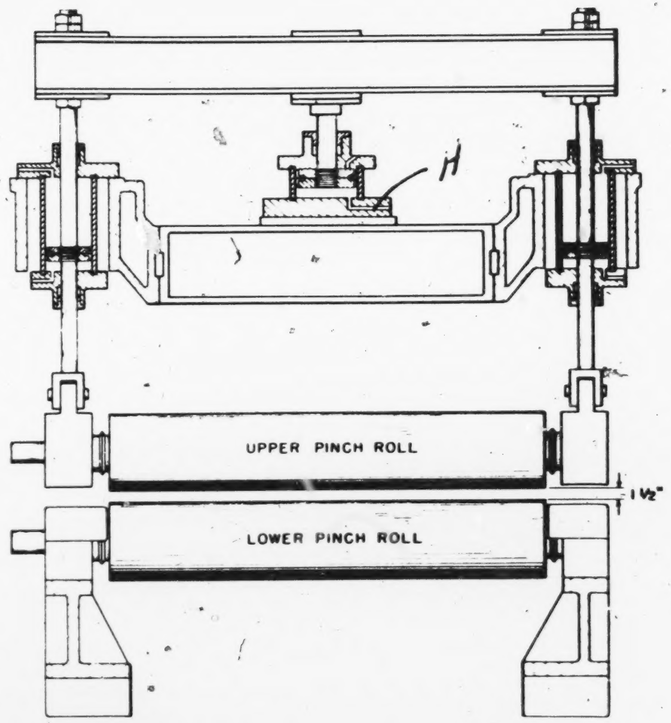
141a
DWG. No. 6

CRUCIBLE HOT STRIP MILL

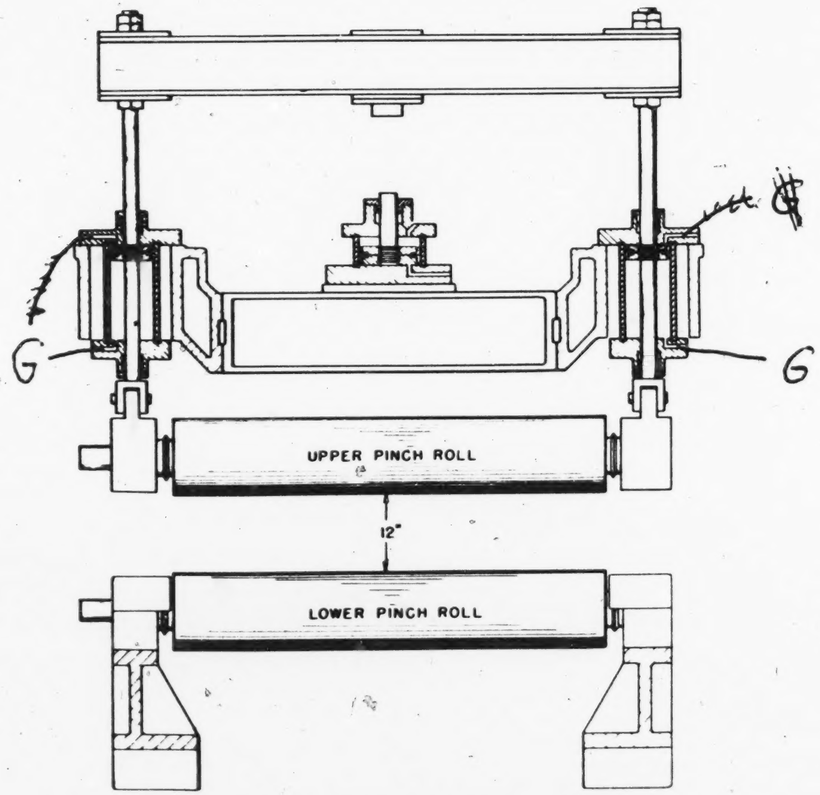
PINCH ROLL OPERATION



PINCH POSITION



LOW LIFT POSITION



HIGH LIFT POSITION

LEGEND:

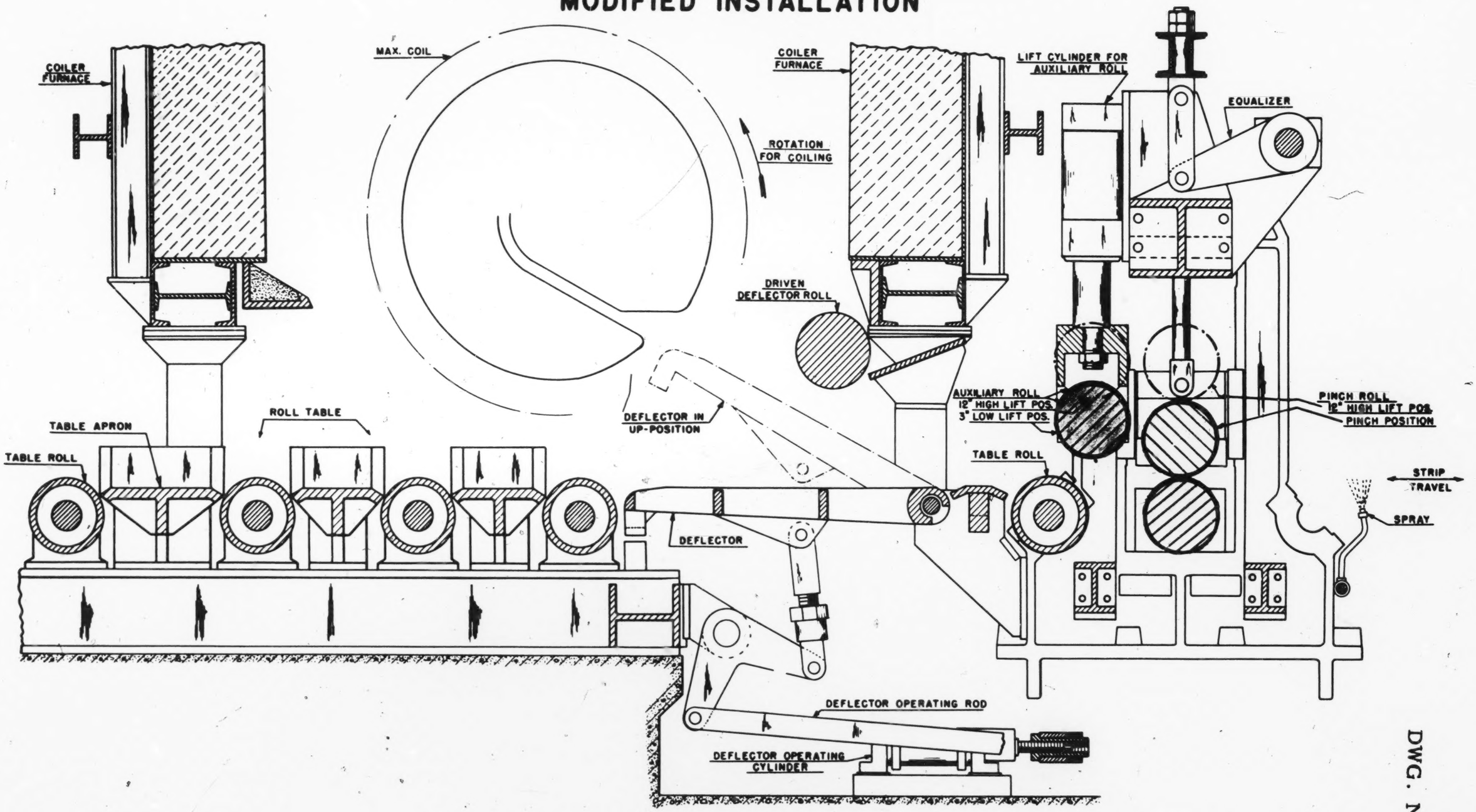
RED SHADED AREA = AREA UNDER AIR PRESSURE

BLUE SHADED AREA = AREA AIRLOCKED (CUSHIONED)

143a

DWG. No. 7

CRUCIBLE HOT STRIP MILL
MODIFIED INSTALLATION

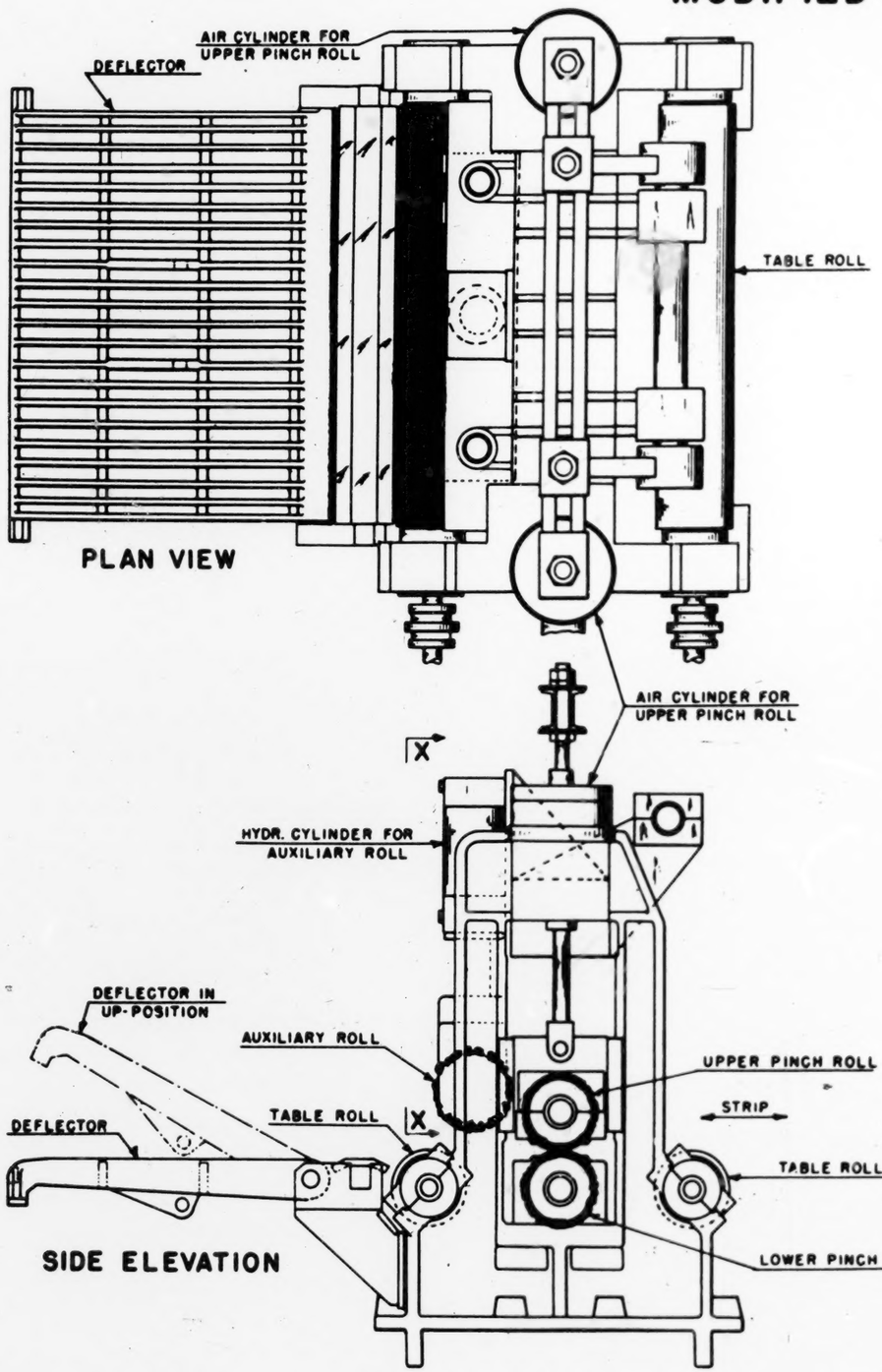


VERTICAL SECTION AT PINCH ROLL & COILER

CRUCIBLE HOT STRIP MILL

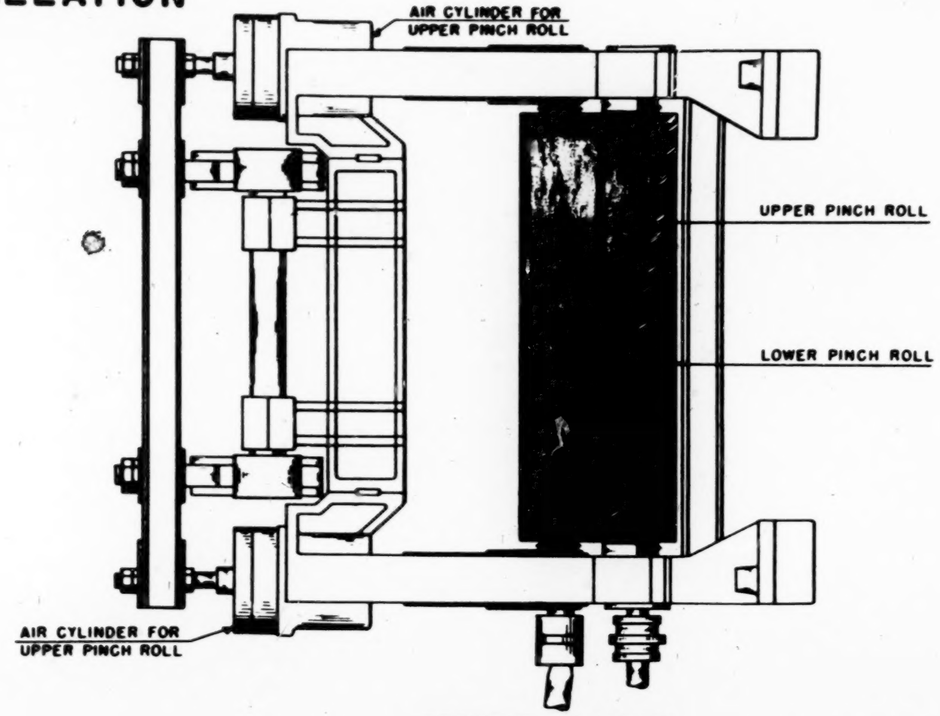
MODIFIED INSTALLATION

DWG. No. 9

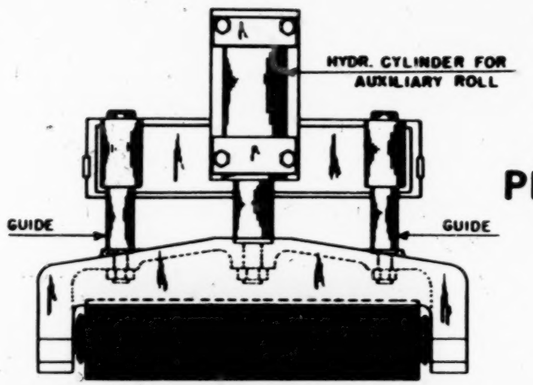


PLAN VIEW

SIDE ELEVATION



FRONT ELEVATION



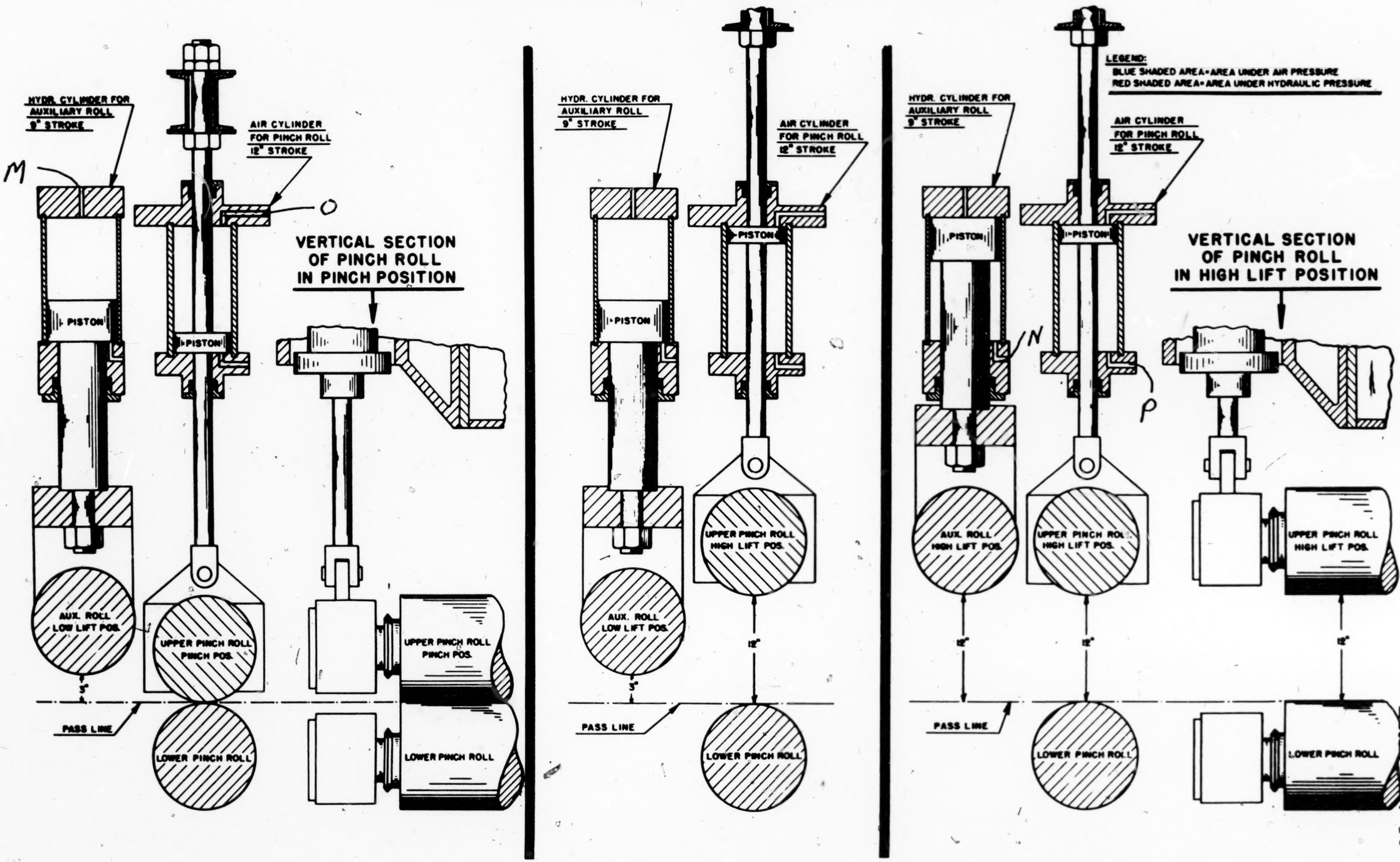
VIEW X-X
AUX. ROLL ARR'G'T.

DEFLECTOR AND PINCH ROLL ASSEMBLY

CRUCIBLE HOT STRIP MILL

PINCH ROLL & AUXILIARY ROLL OPERATION

DWG. No. 10



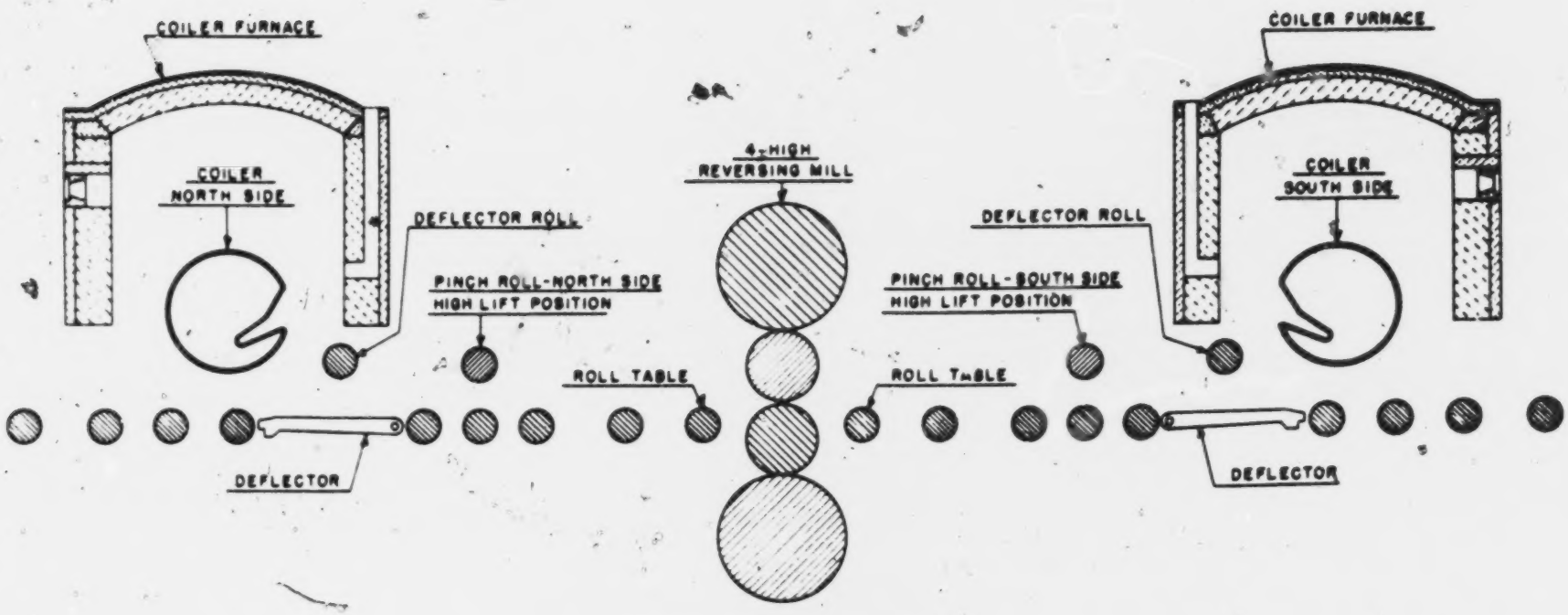
DRG. No. 10

149a

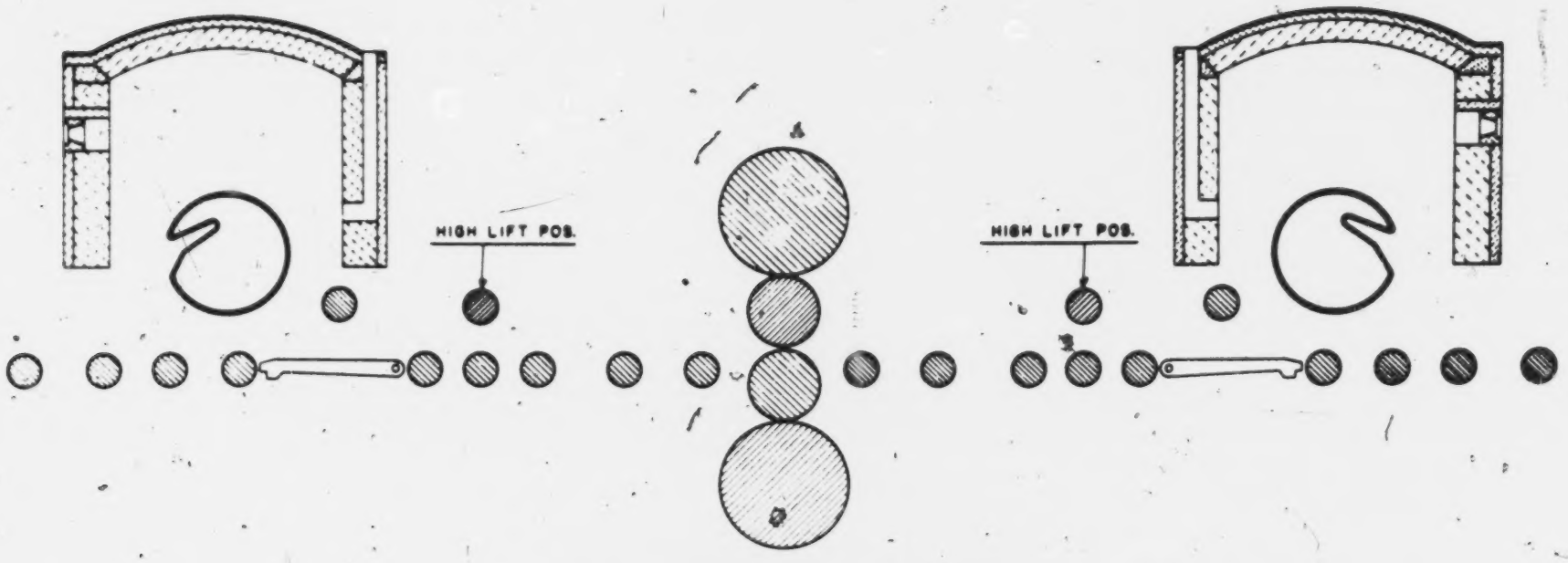
DWG. No. 11

CRUCIBLE HOT STRIP MILL

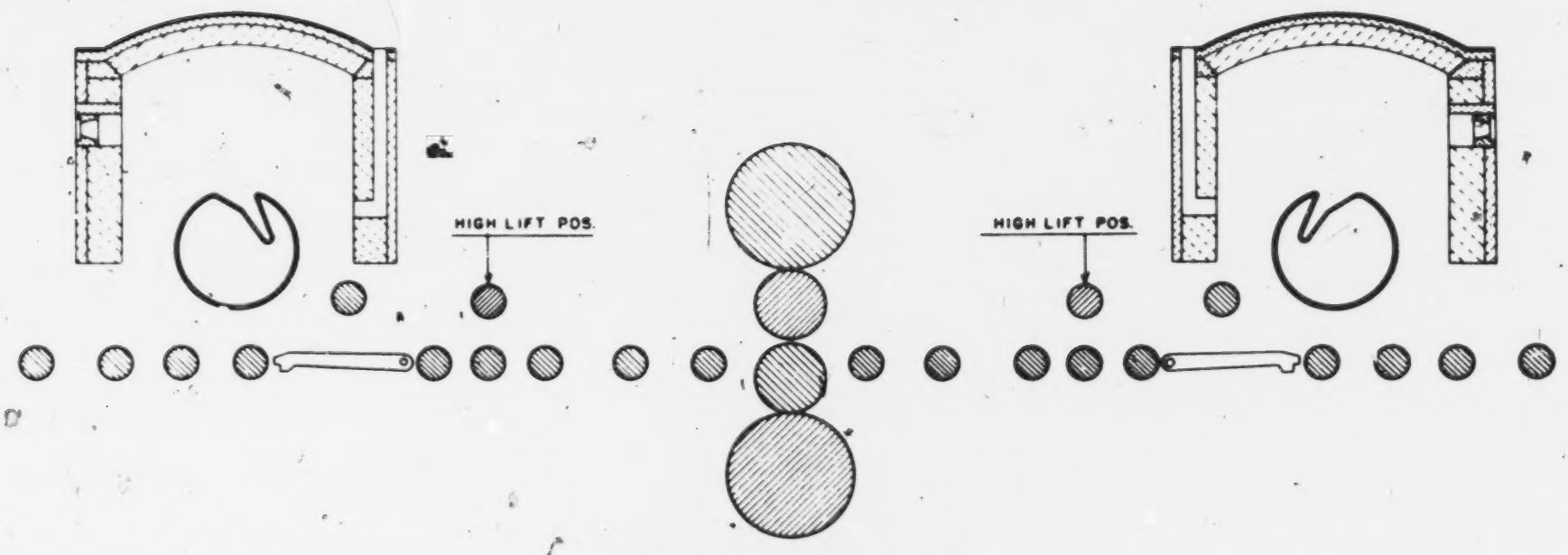
OPERATION OF ORIGINAL MILL



FIRST PASS STARTED



FIRST PASS DURING ROLLING

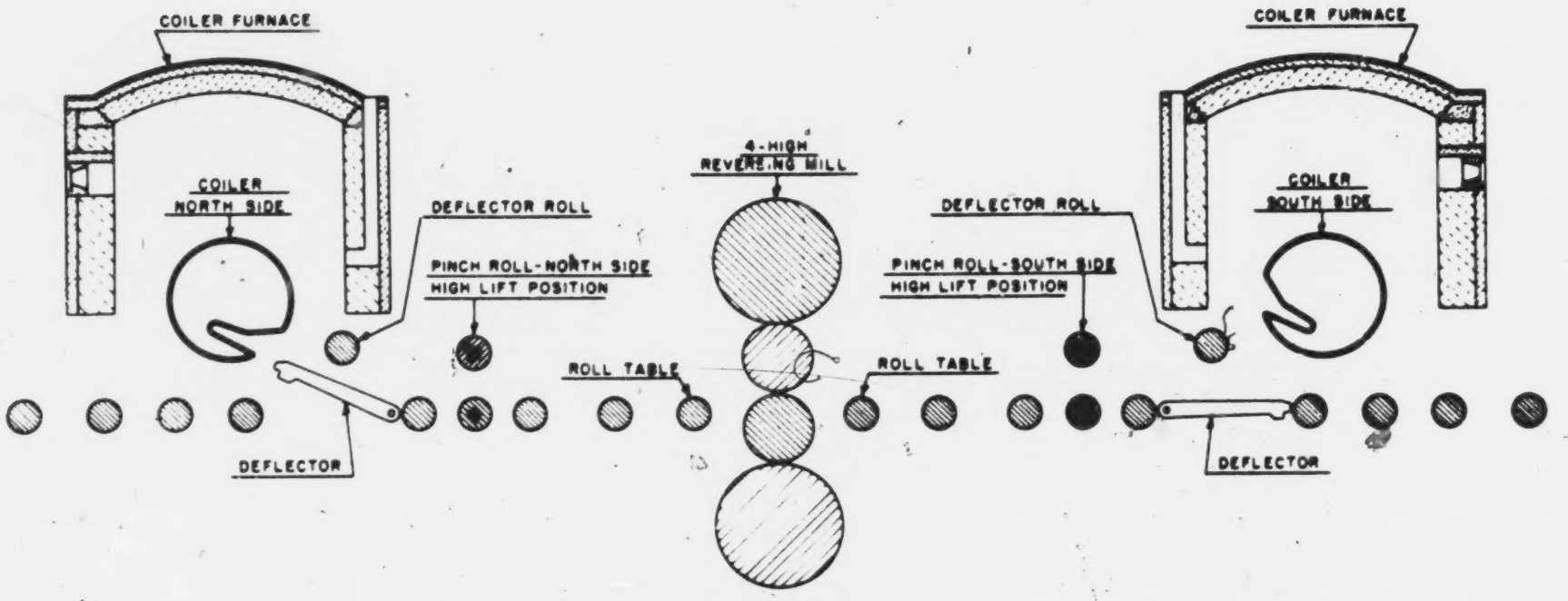


FIRST PASS COMPLETED

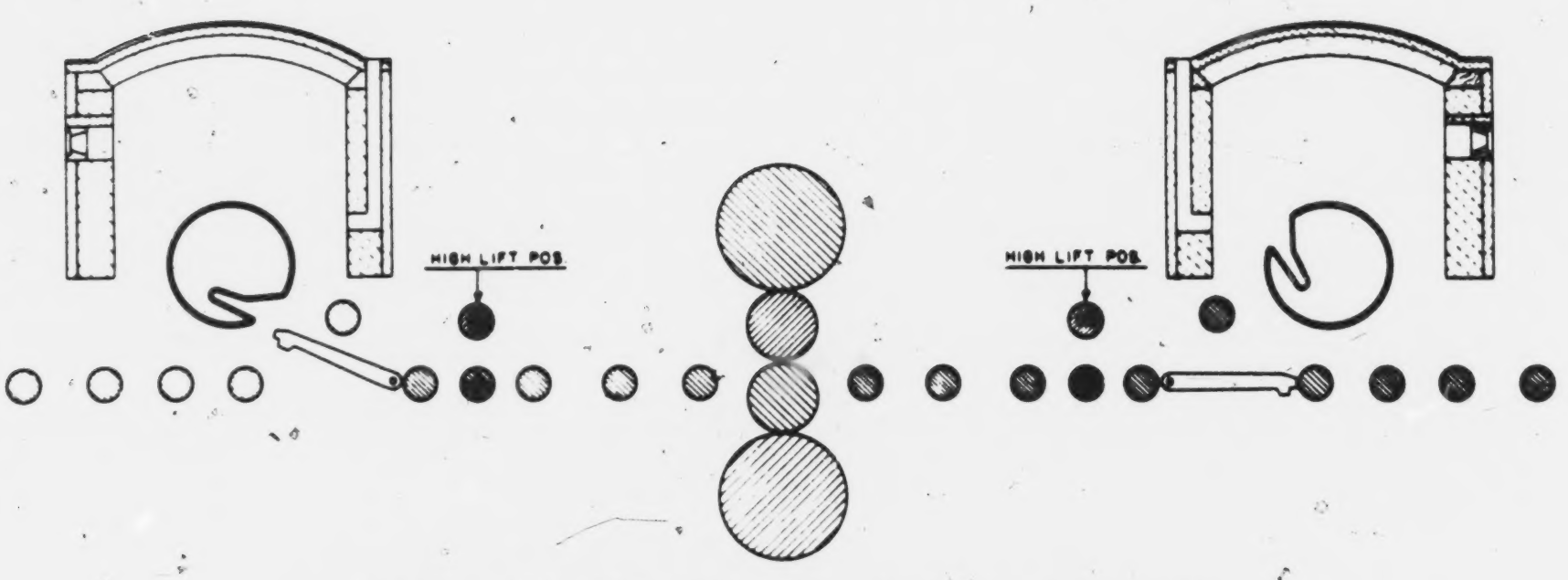
DWG. No. 12

CRUCIBLE HOT STRIP MILL

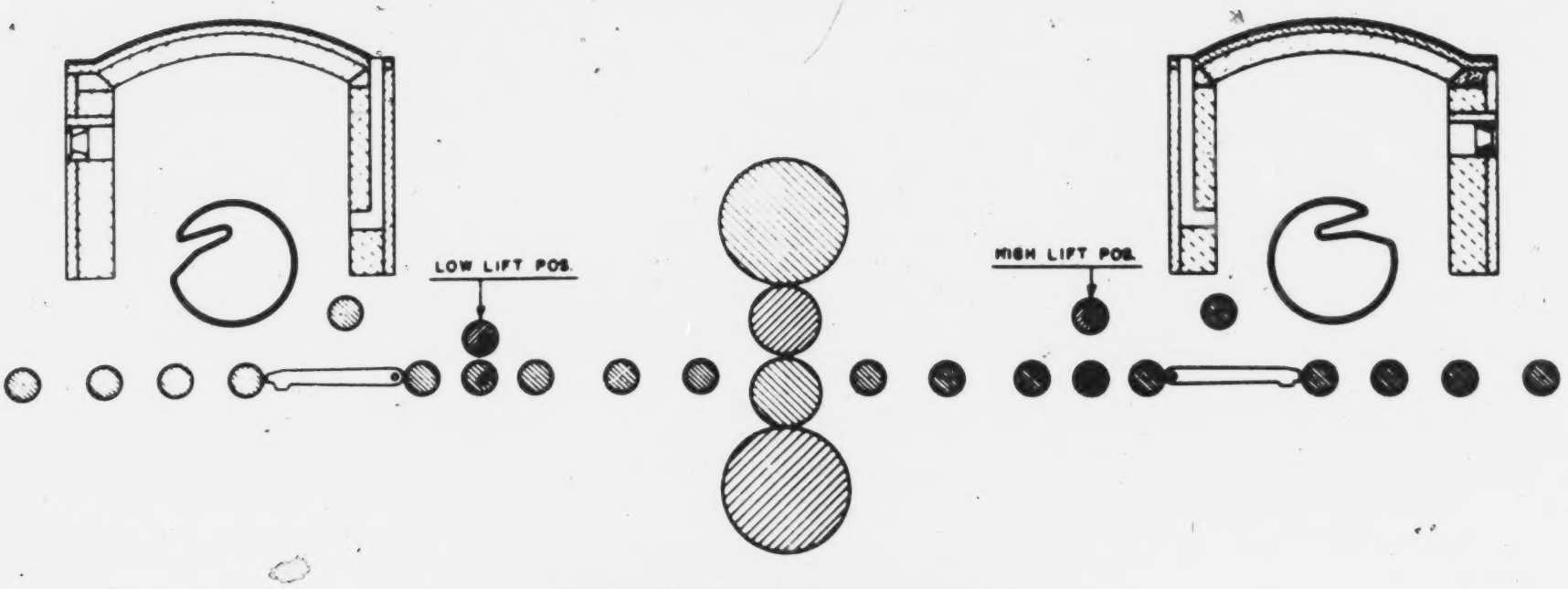
OPERATION OF ORIGINAL MILL



SECOND PASS STARTED



SECOND PASS - STRIP ENTERING COILER ON NORTH SIDE

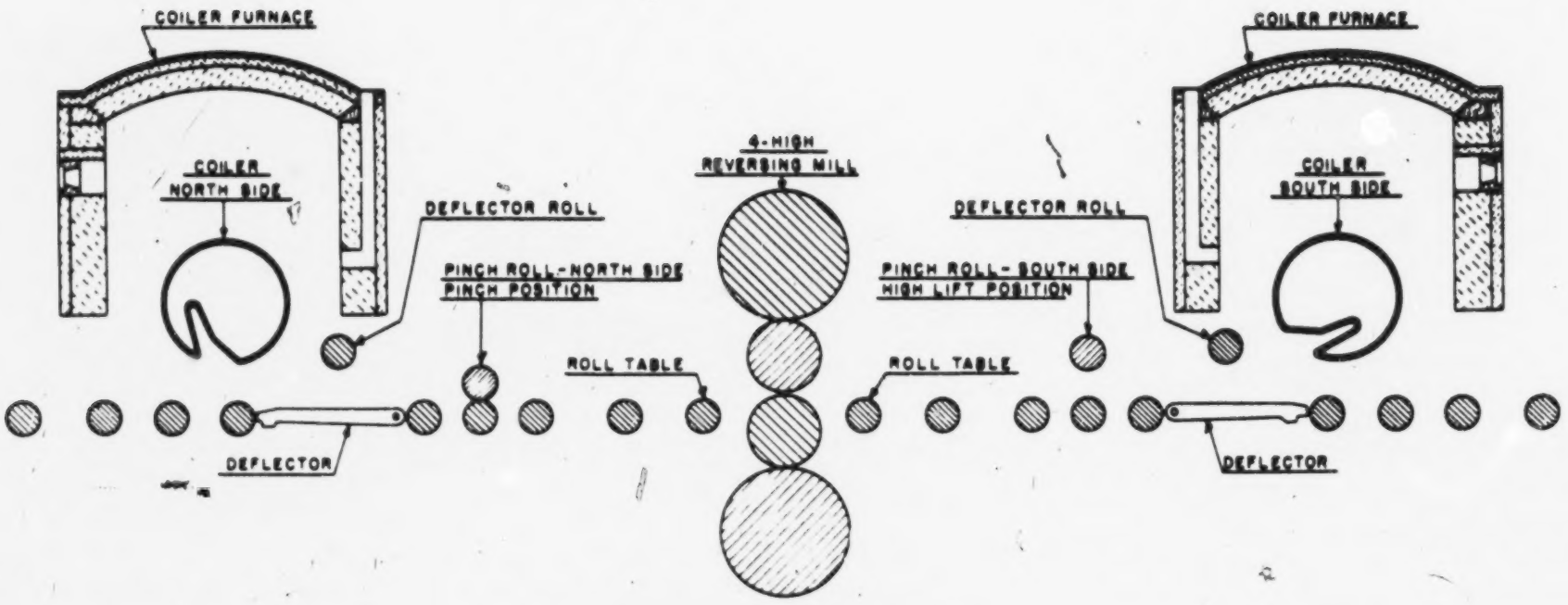


SECOND PASS DURING ROLLING

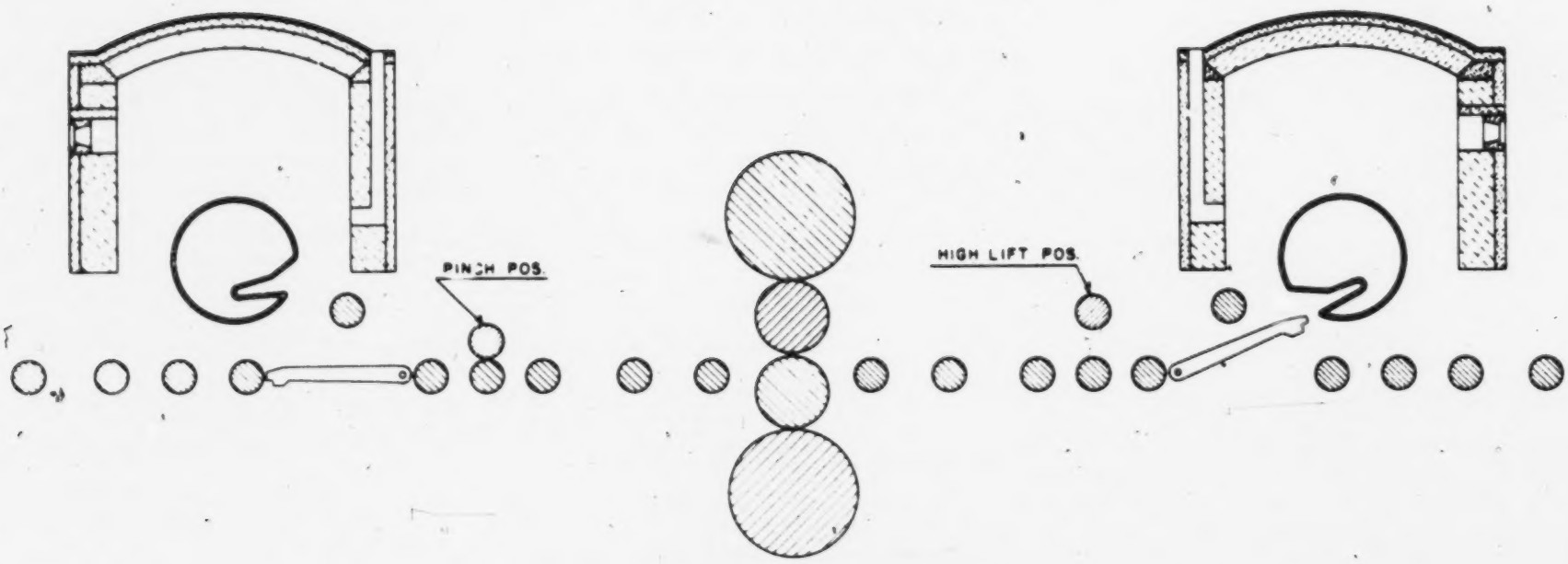
DWG. No. 13

CRUCIBLE HOT STRIP MILL

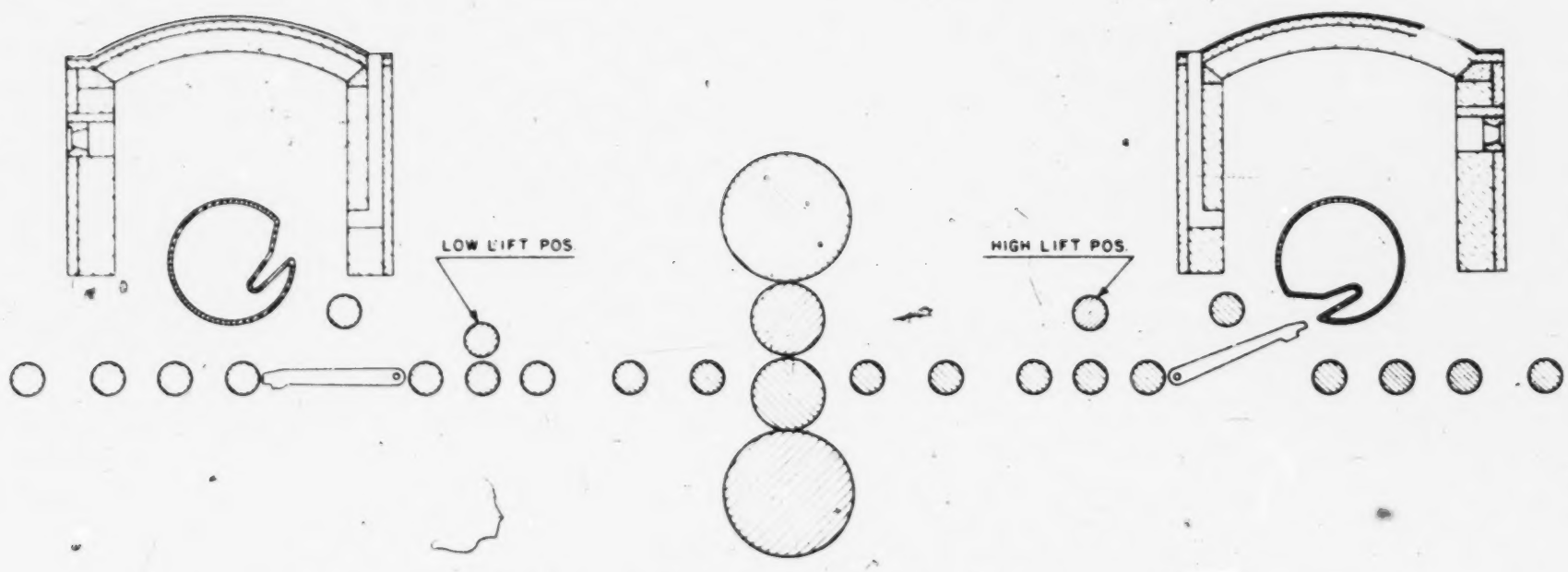
OPERATION OF ORIGINAL MILL



SECOND PASS COMPLETED



THIRD PASS STARTED

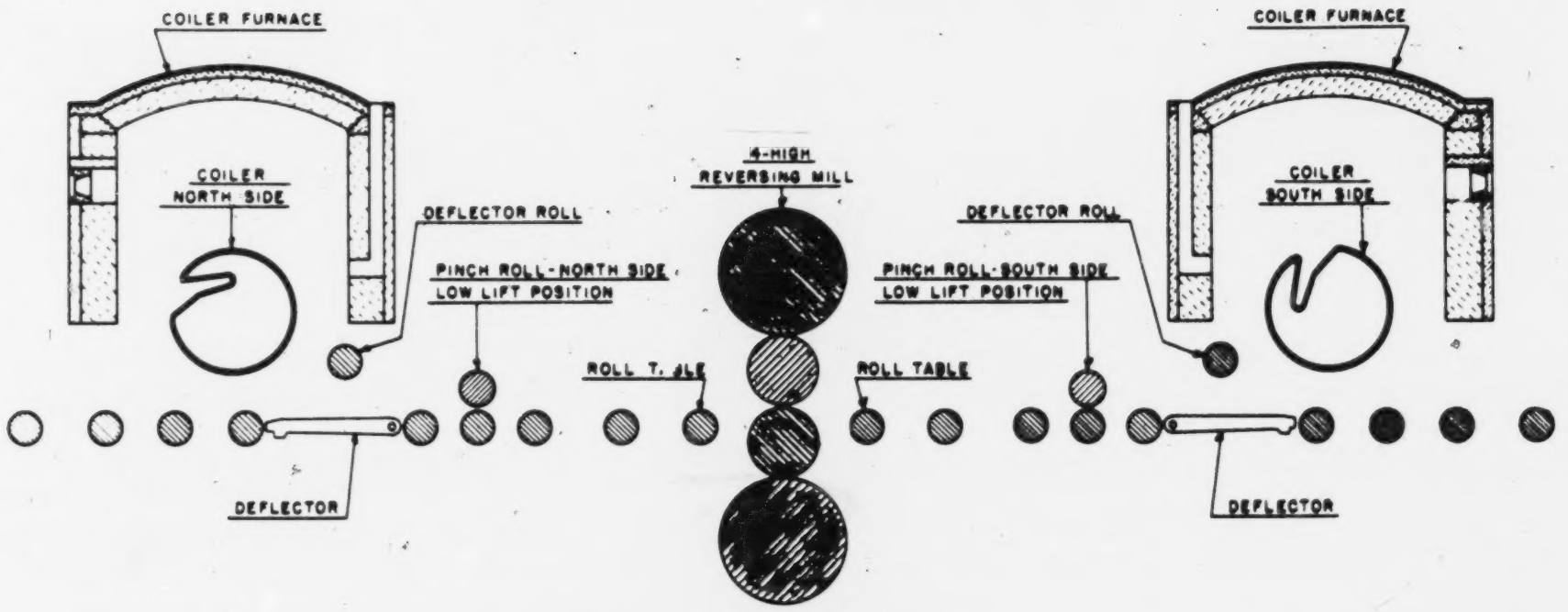


THIRD PASS - STRIP ENTERING COILER ON SOUTH SIDE

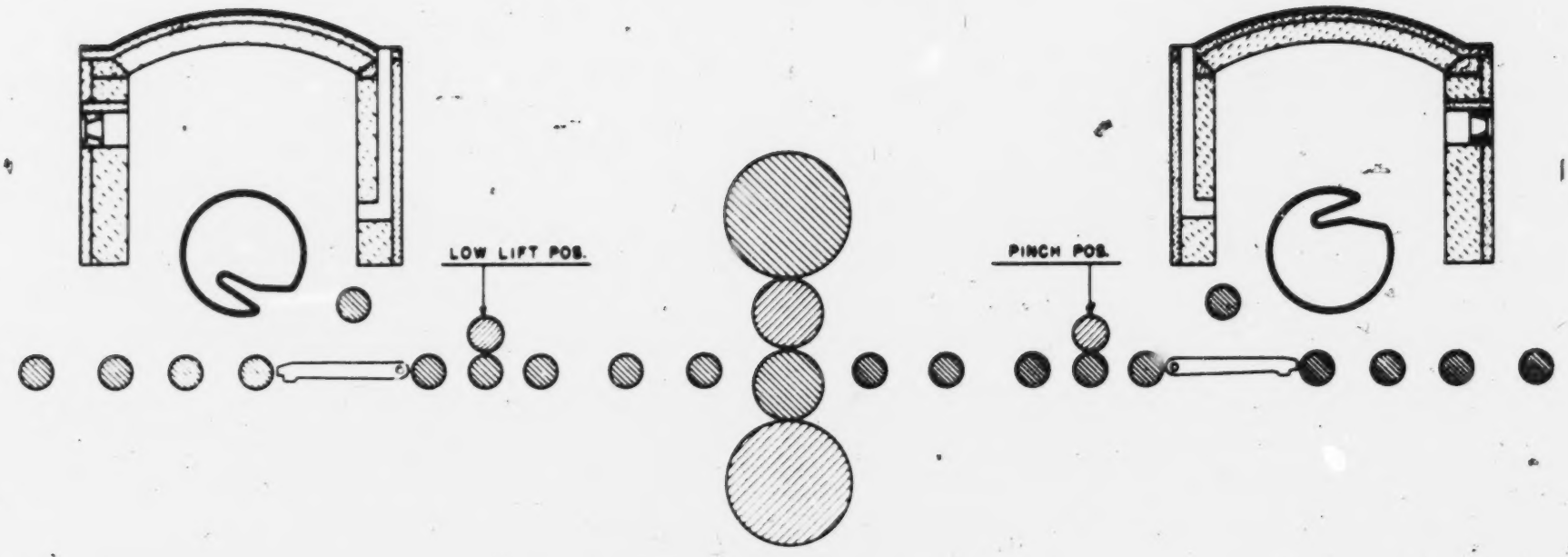
DWG. No. 14

CRUCIBLE HOT STRIP MILL

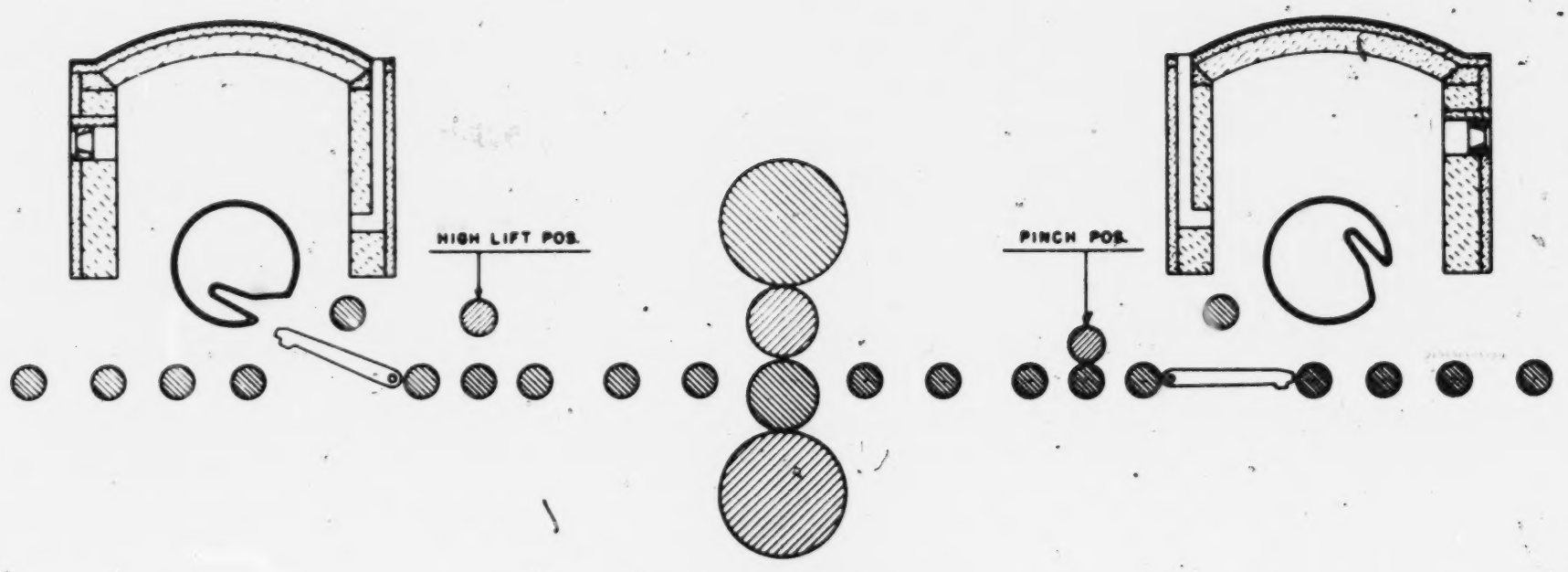
OPERATION OF ORIGINAL MILL



THIRD PASS DURING ROLLING



THIRD PASS COMPLETED

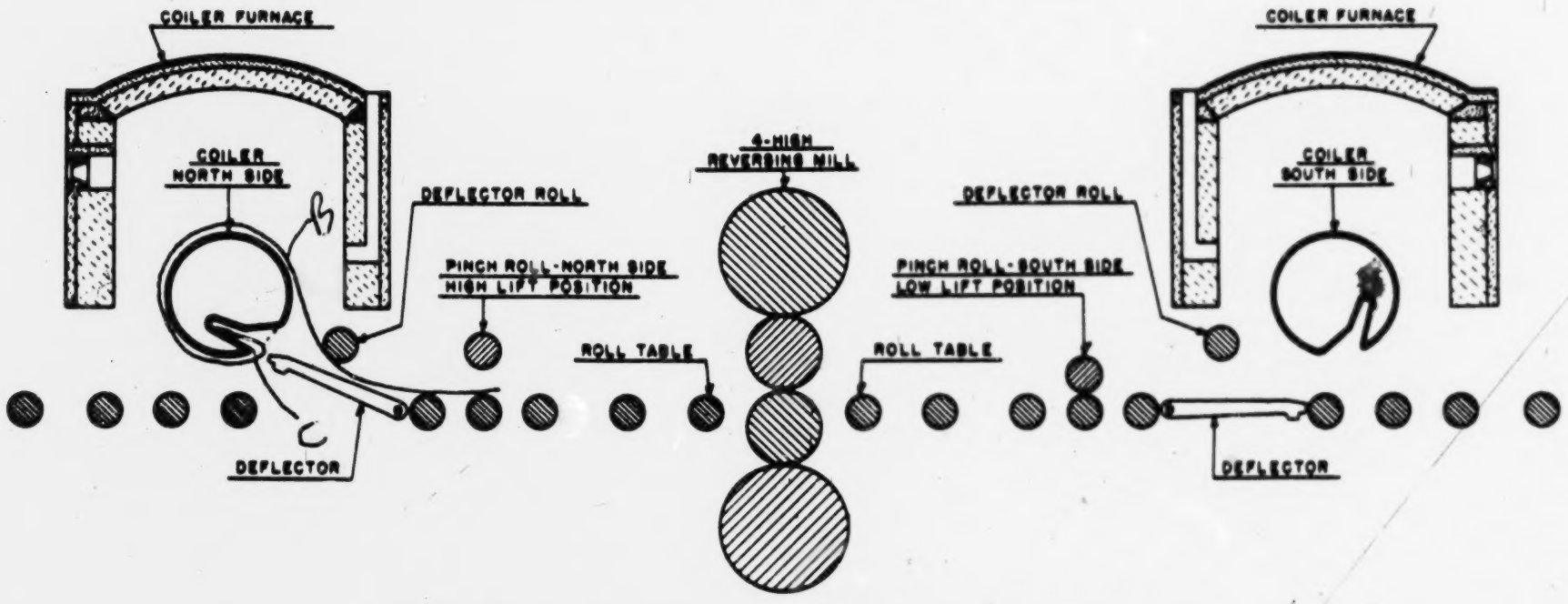


FOURTH PASS STARTED

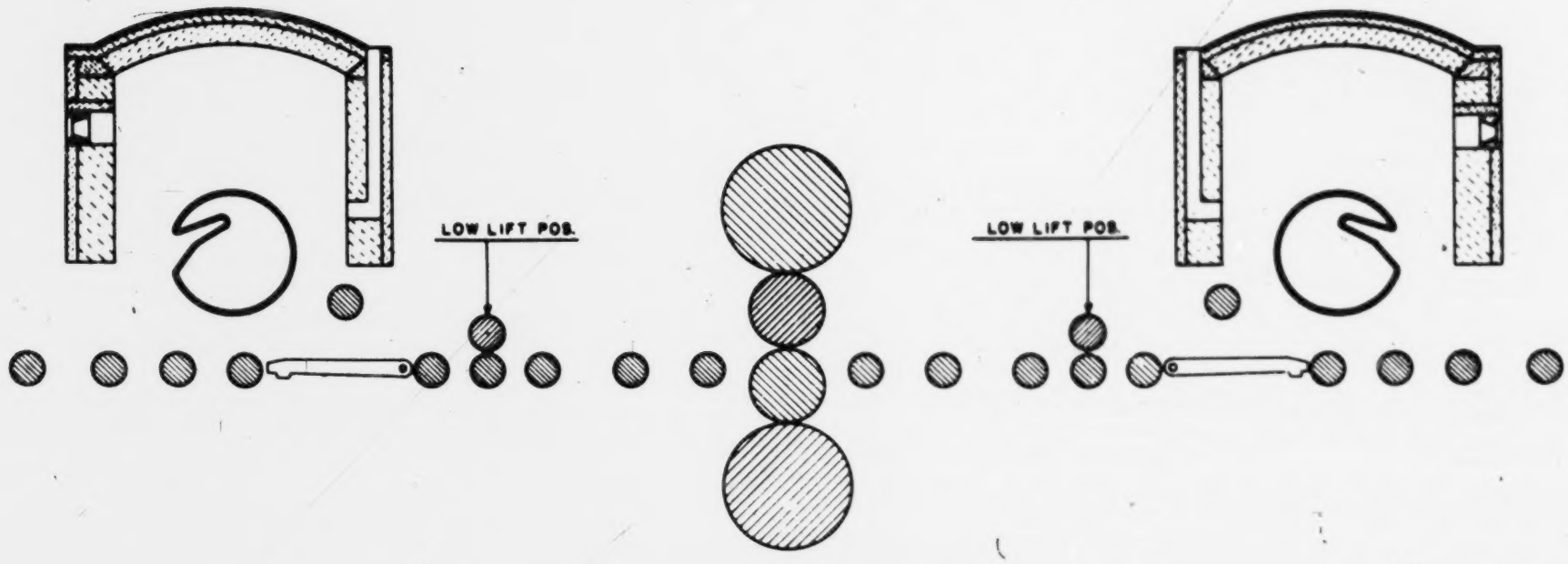
DWG. No. 15

CRUCIBLE HOT STRIP MILL

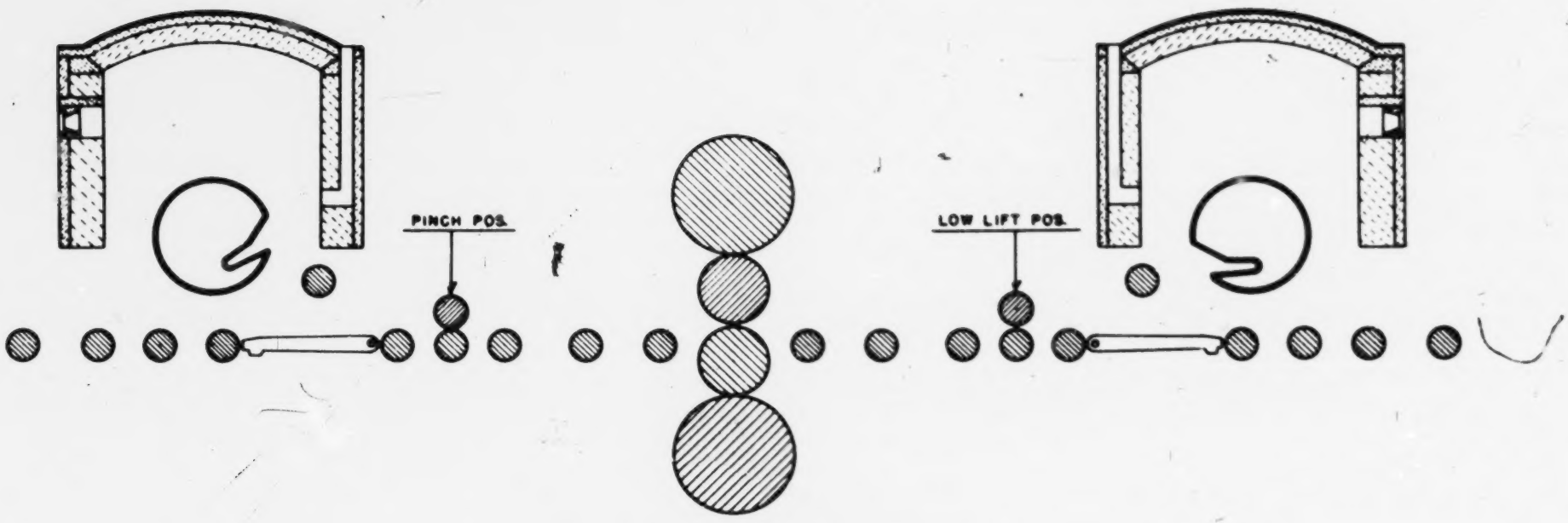
OPERATION OF ORIGINAL MILL



FOURTH PASS - STRIP ENTERING COILER ON NORTH SIDE



FOURTH PASS DURING ROLLING

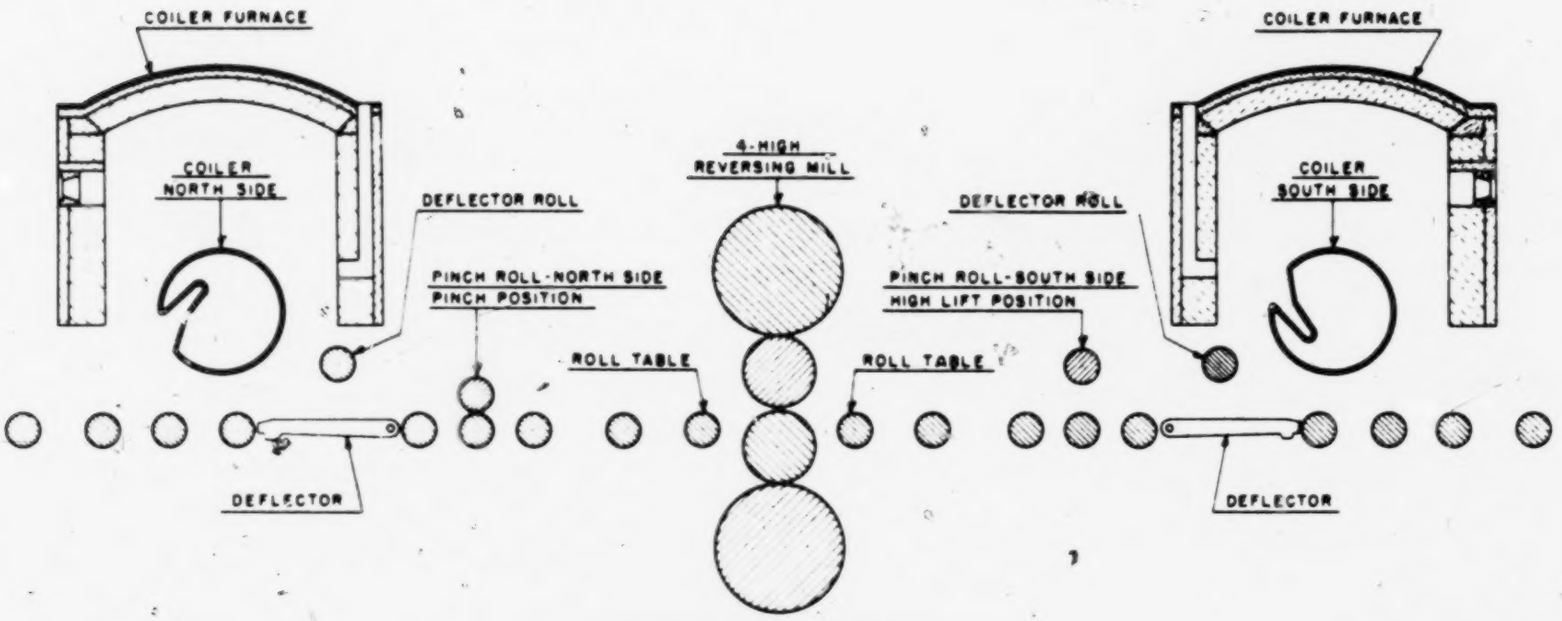


FOURTH PASS COMPLETED

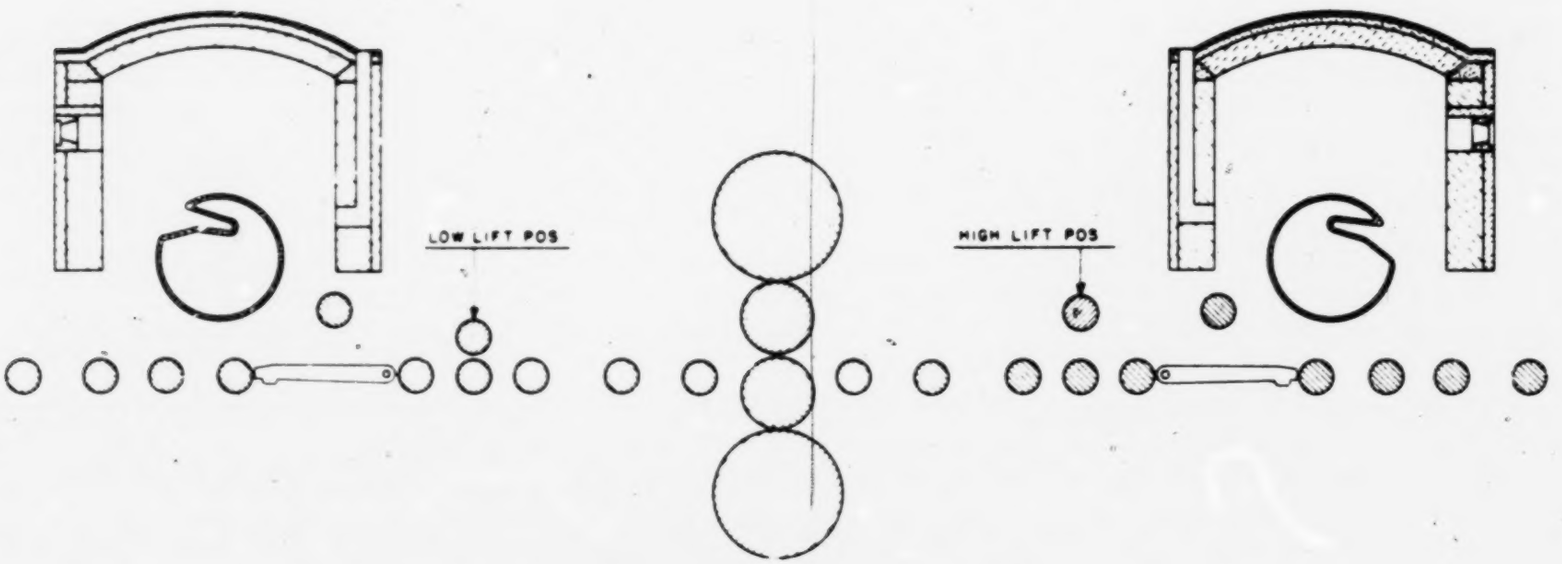
DWG. No. 16

CRUCIBLE HOT STRIP MILL

OPERATION OF ORIGINAL MILL



FINAL PASS STARTED

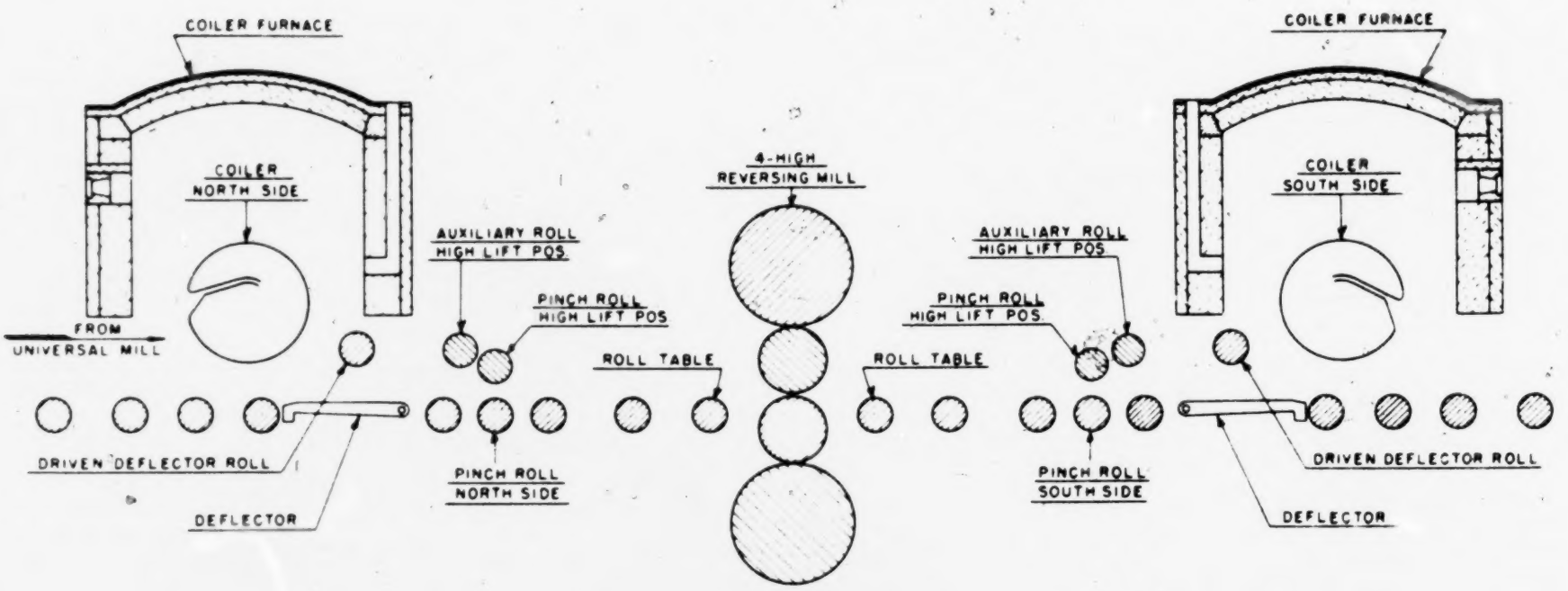


FINAL PASS DURING ROLLING

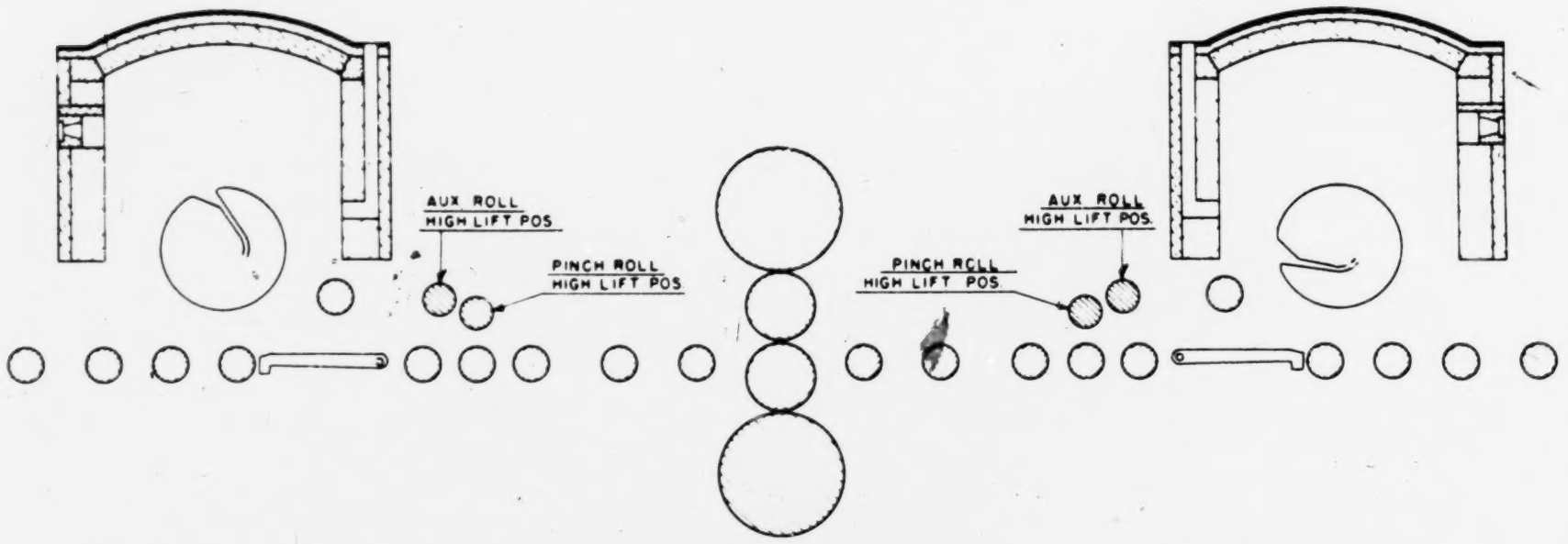
DWG. No. 17

CRUCIBLE HOT STRIP MILL

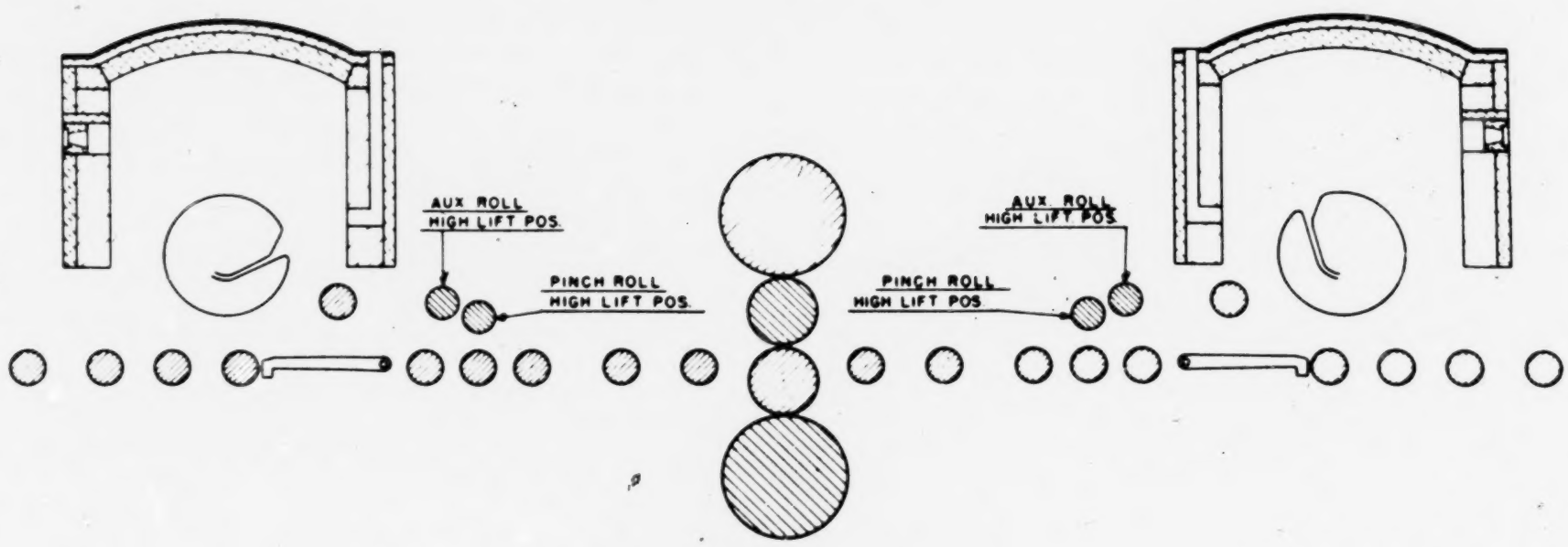
OPERATION OF MODIFIED MILL



FIRST PASS STARTED



FIRST PASS ROLLING

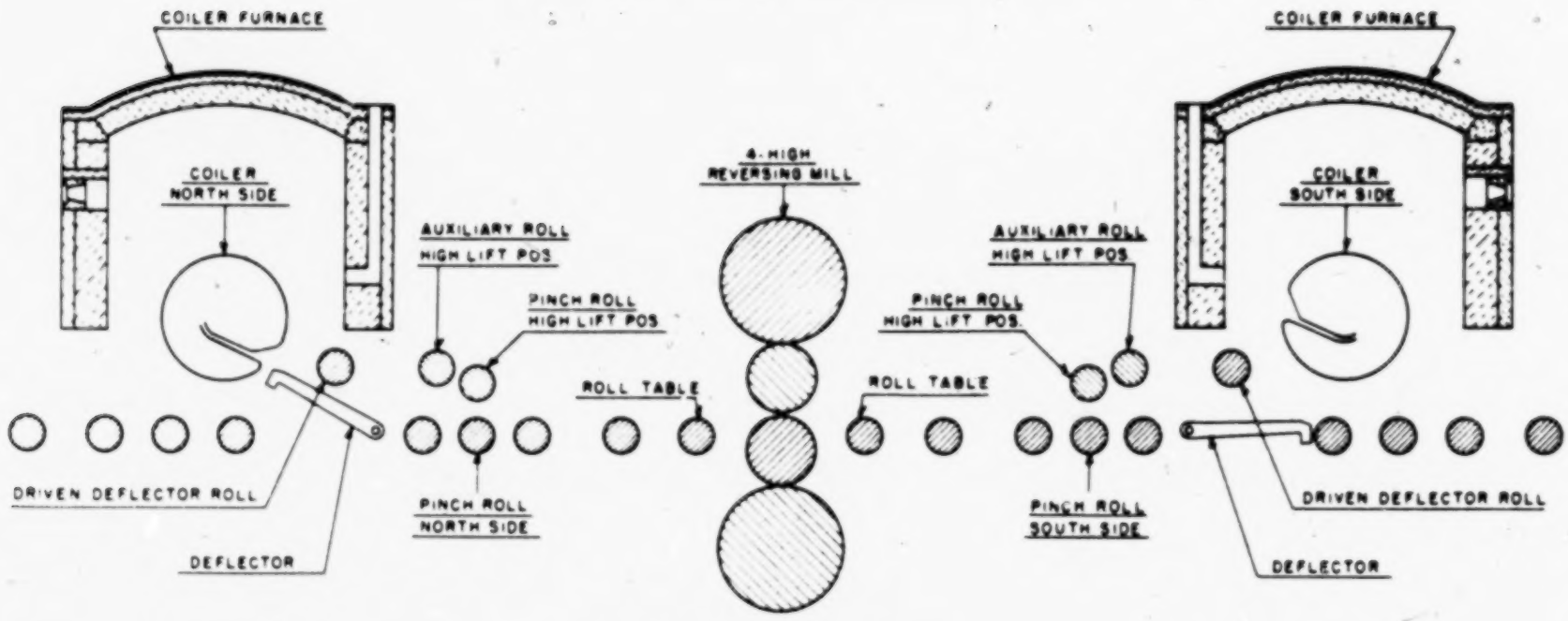


FIRST PASS COMPLETED

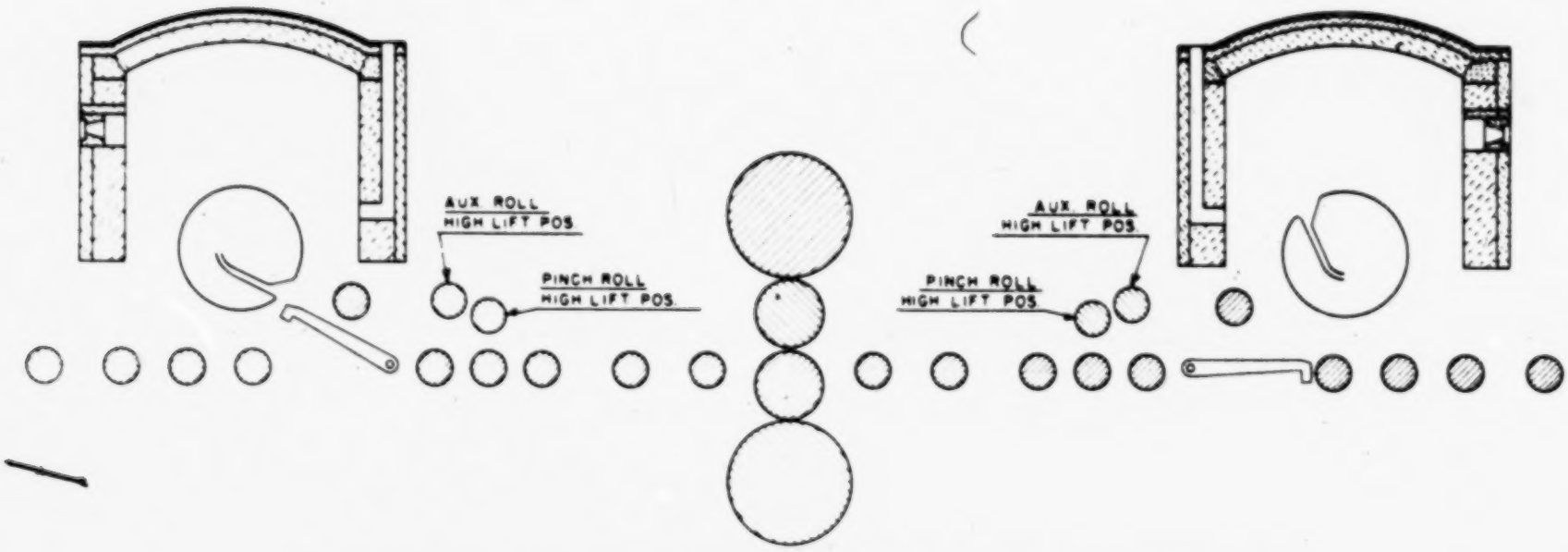
DWG. No. 18

CRUCIBLE HOT STRIP MILL

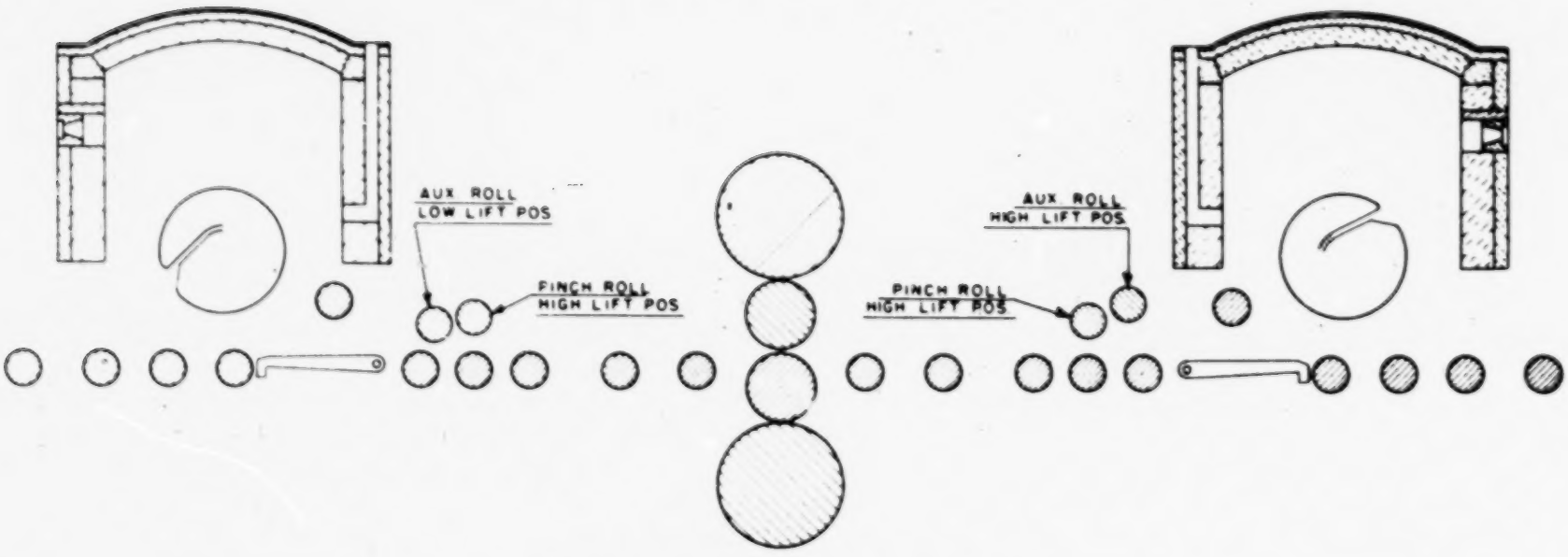
OPERATION OF MODIFIED MILL



SECOND PASS STARTED



SECOND PASS-STRIP ENTERING COILER ON NORTH SIDE

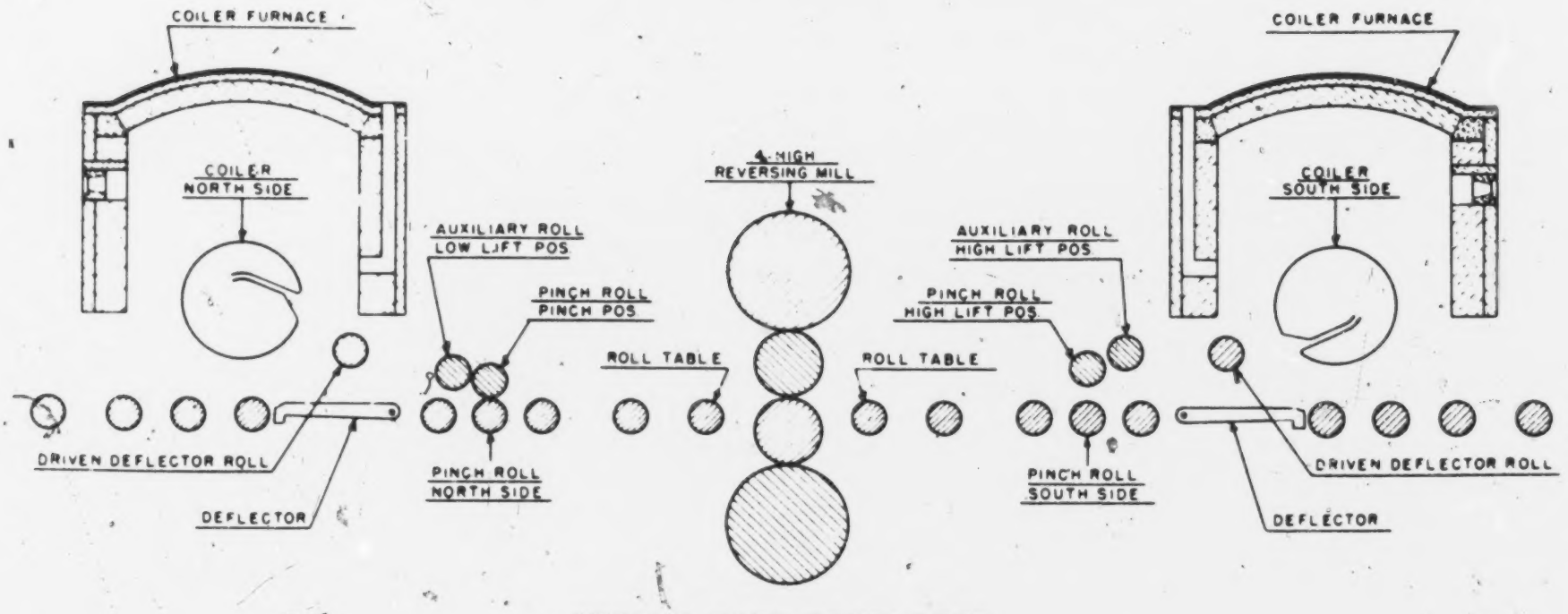


SECOND PASS DURING ROLLING

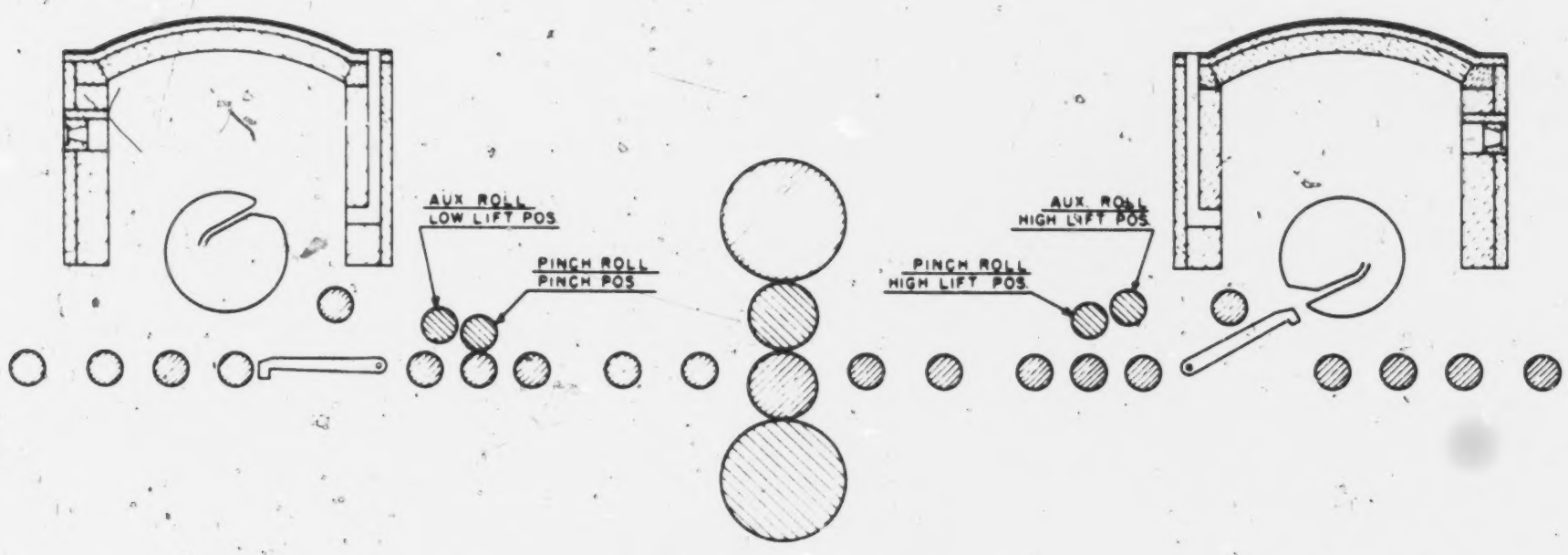
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CRUCIBLE HOT STRIP MILL

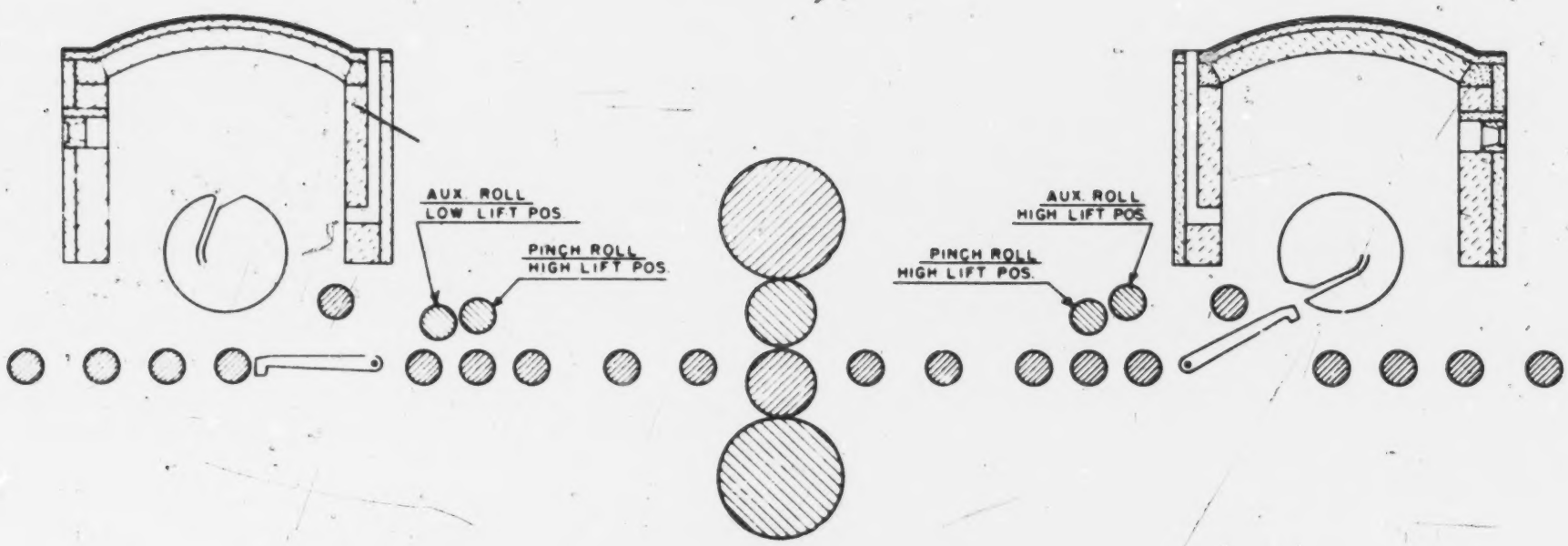
OPERATION OF MODIFIED MILL



SECOND PASS COMPLETED



THIRD PASS STARTED

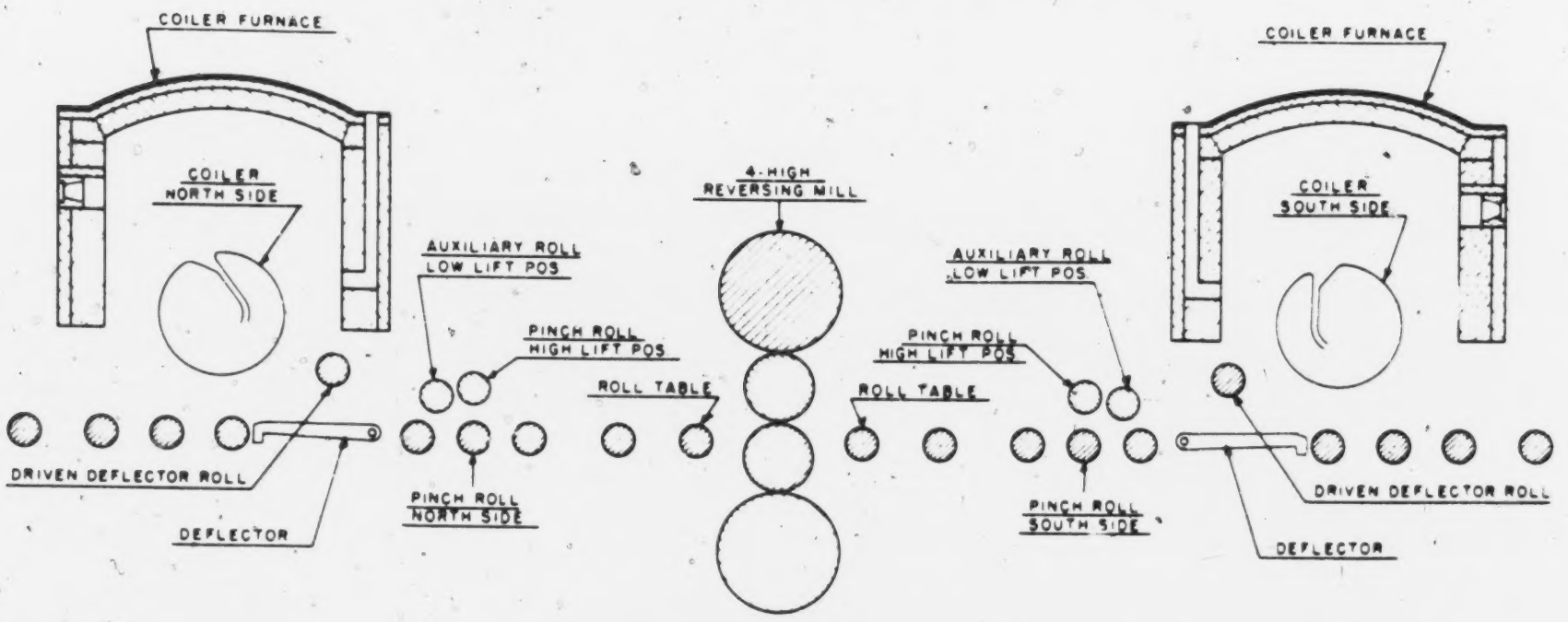


THIRD PASS - STRIP ENTERING COILER ON SOUTH SIDE

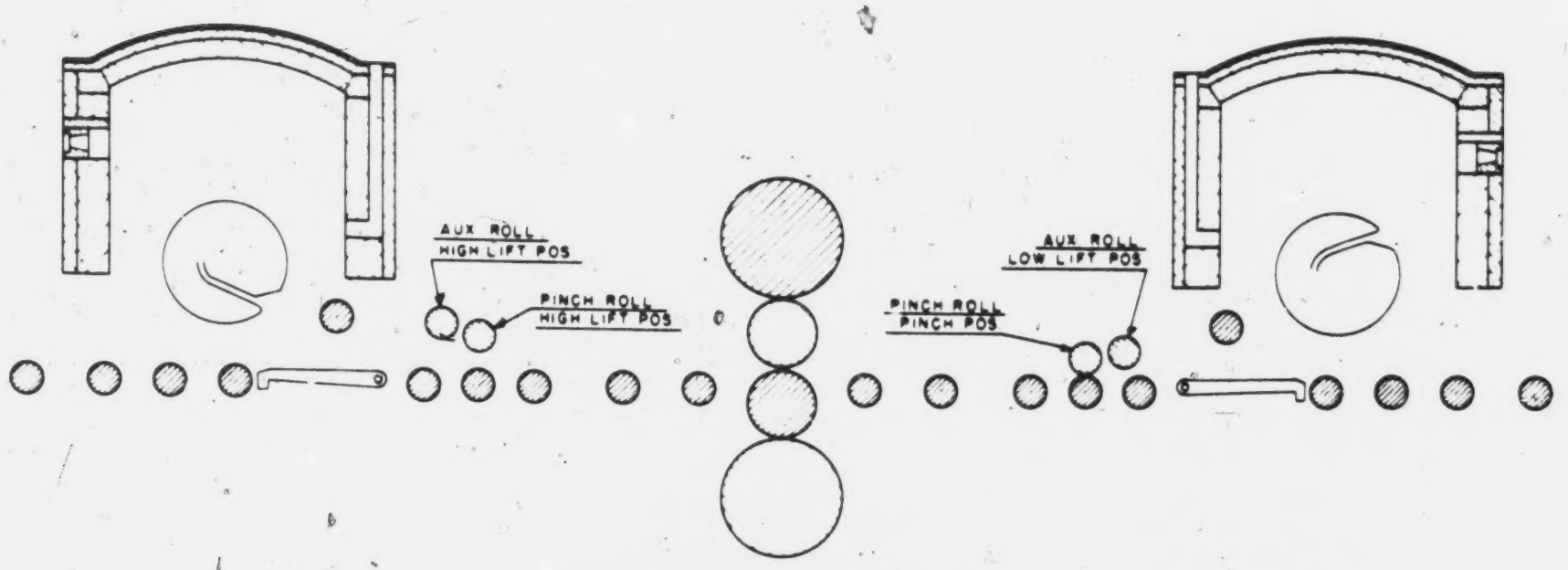
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CRUCIBLE HOT STRIP MILL

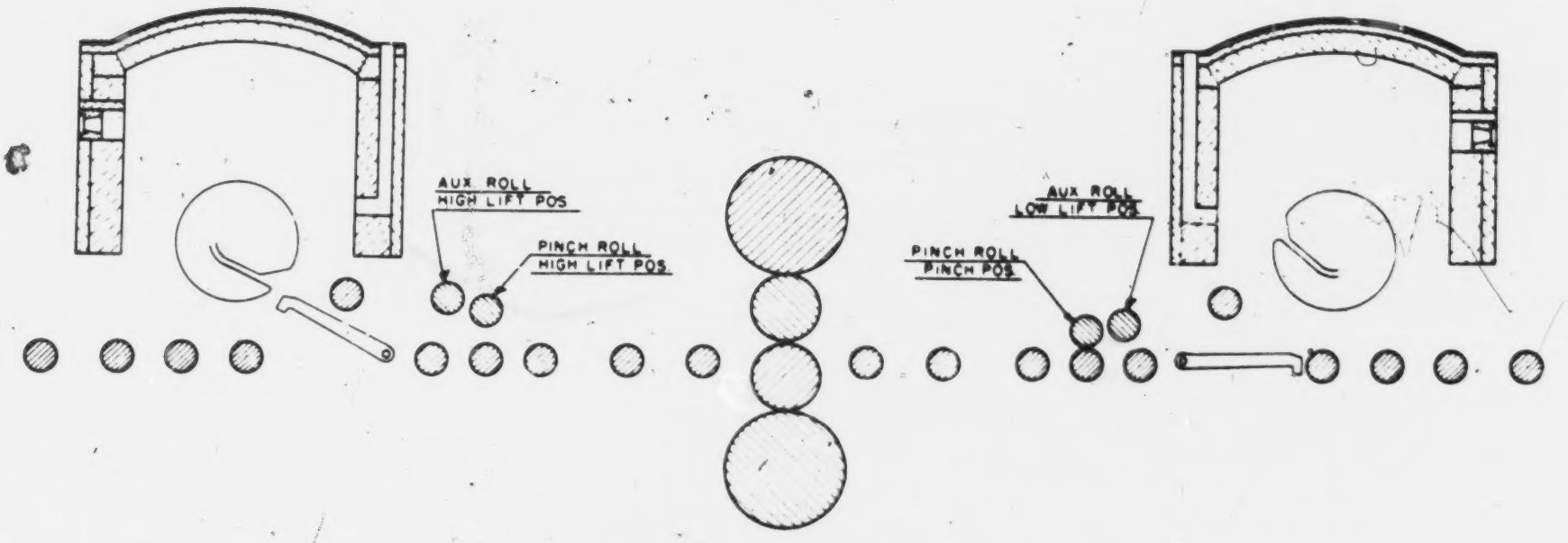
OPERATION OF MODIFIED MILL



THIRD PASS DURING ROLLING



THIRD PASS COMPLETED

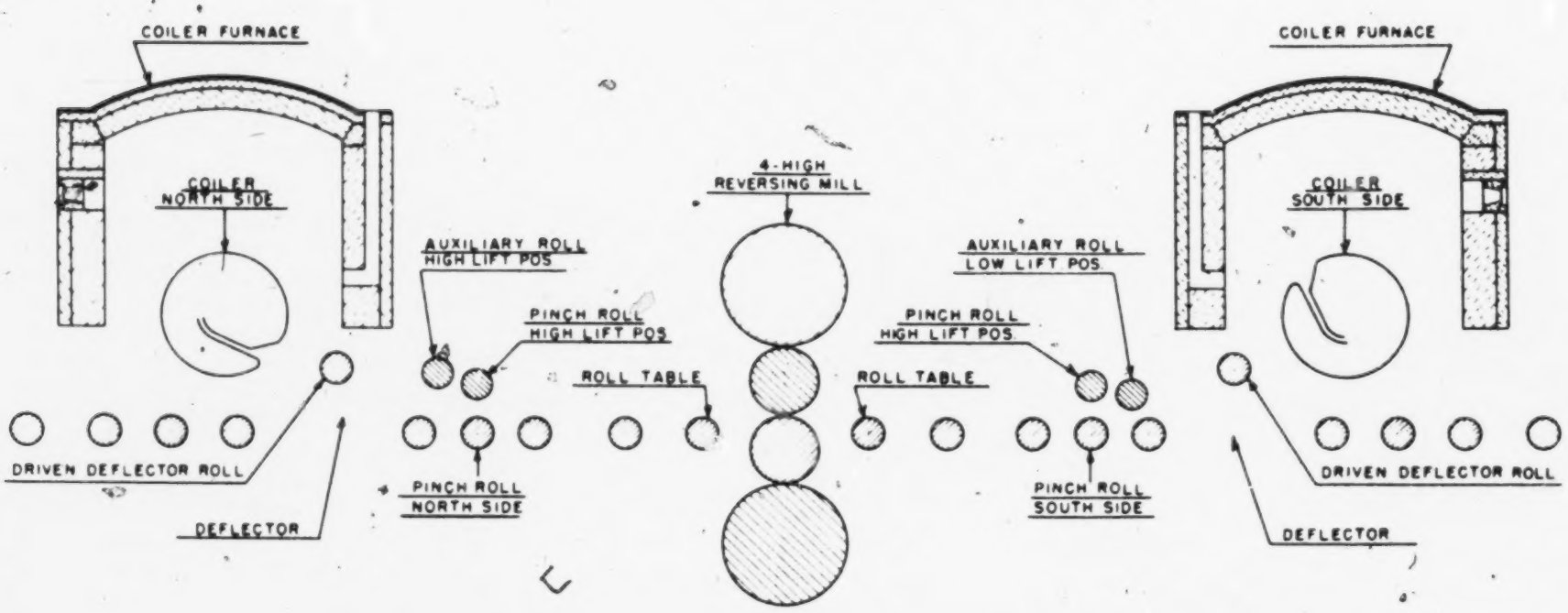


FOURTH PASS STARTED

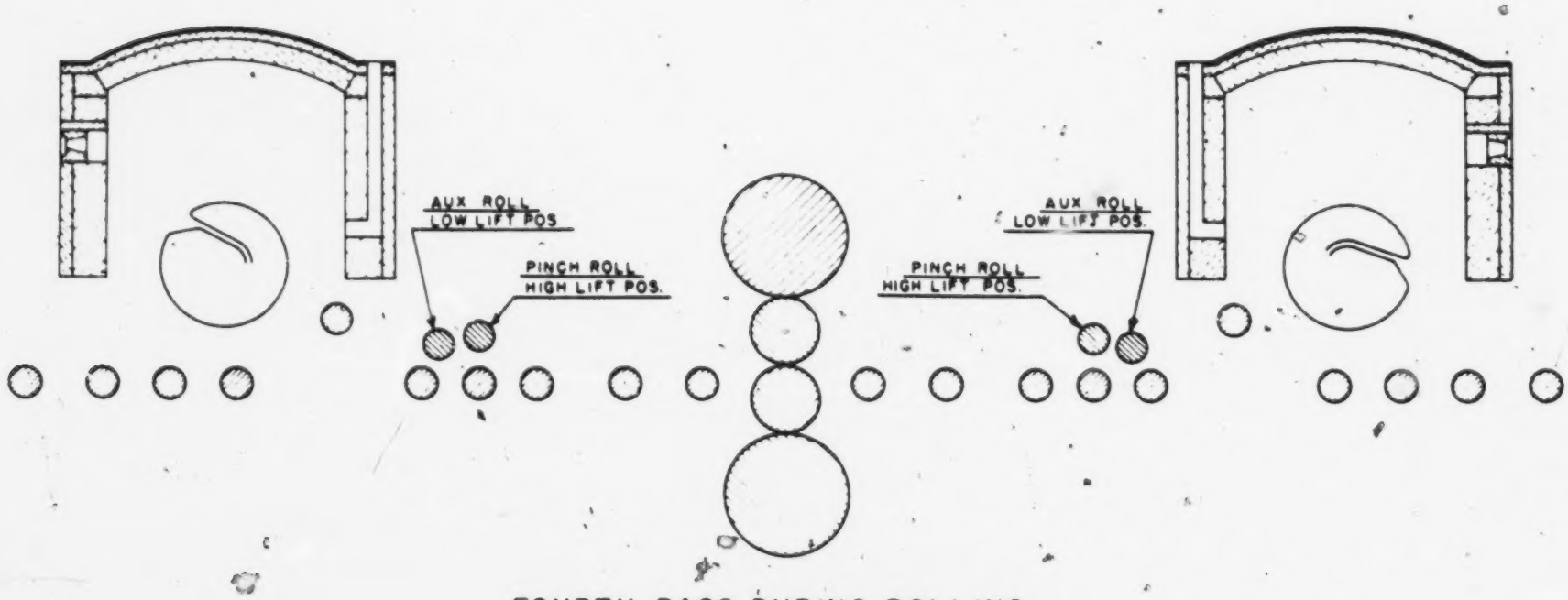
DWG. No. 21

CRUCIBLE HOT STRIP MILL

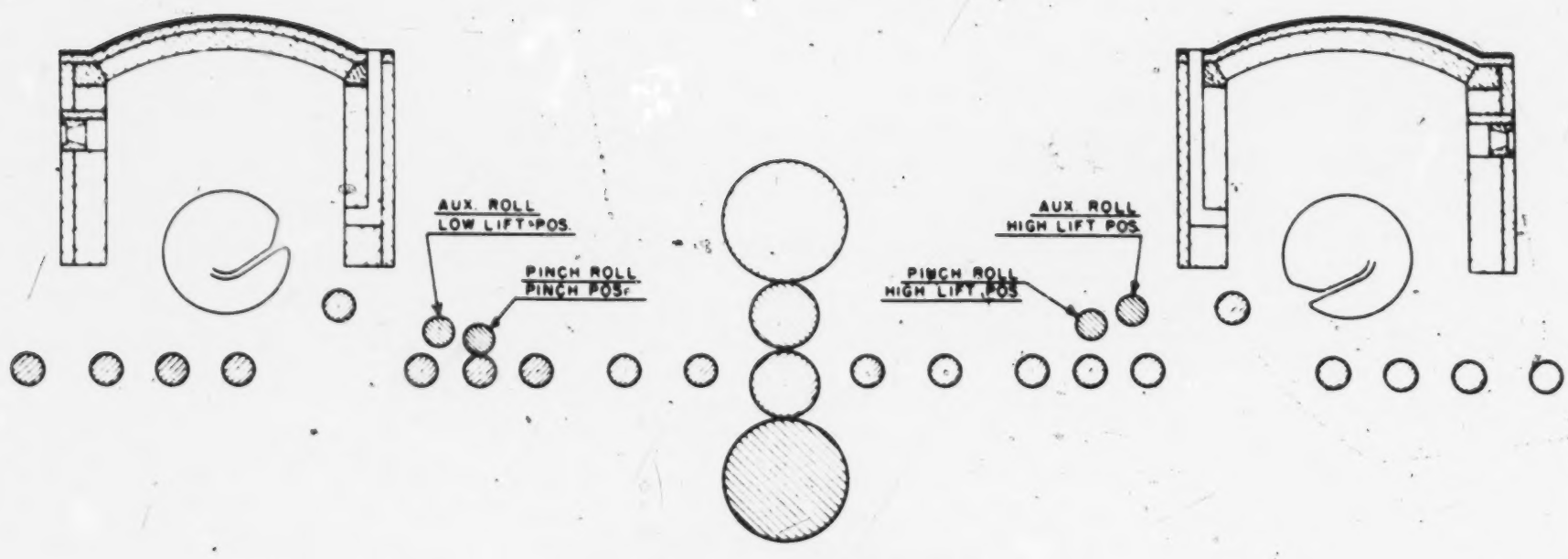
OPERATION OF MODIFIED MILL



FOURTH PASS-STRIP ENTERING COILER ON NORTH SIDE



FOURTH PASS DURING ROLLING

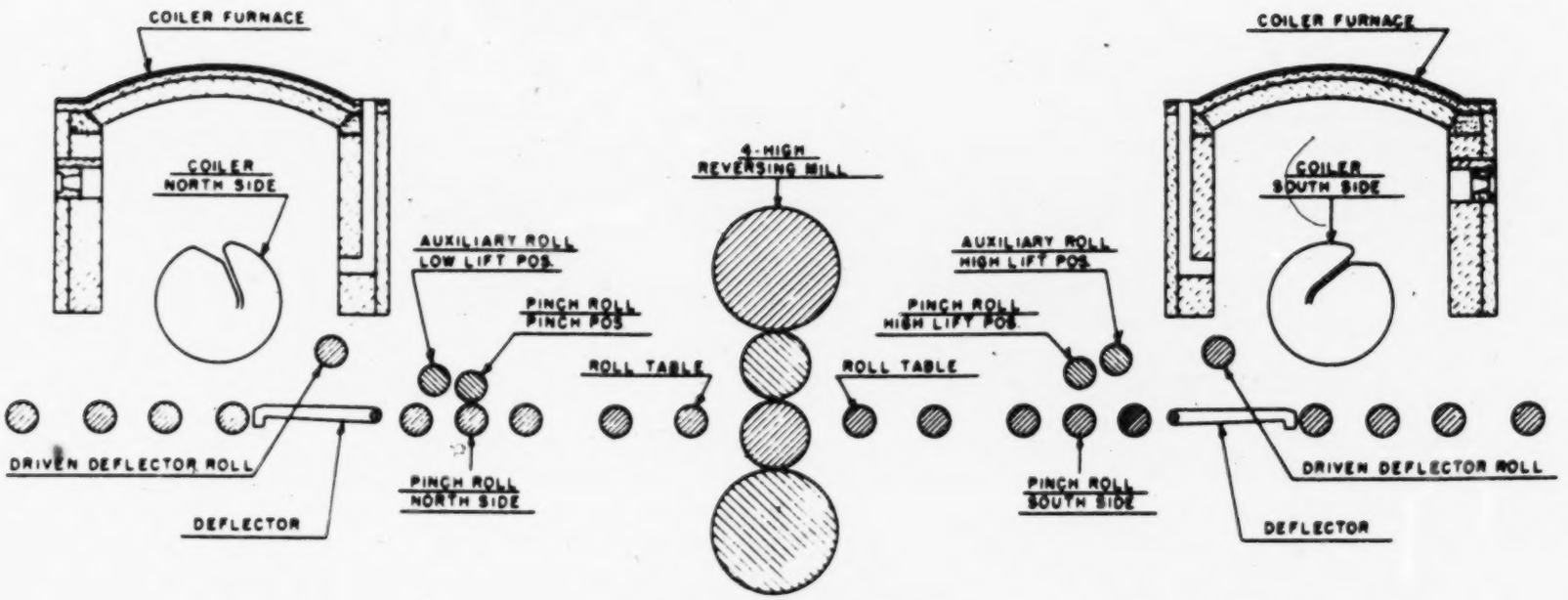


FOURTH PASS COMPLETED

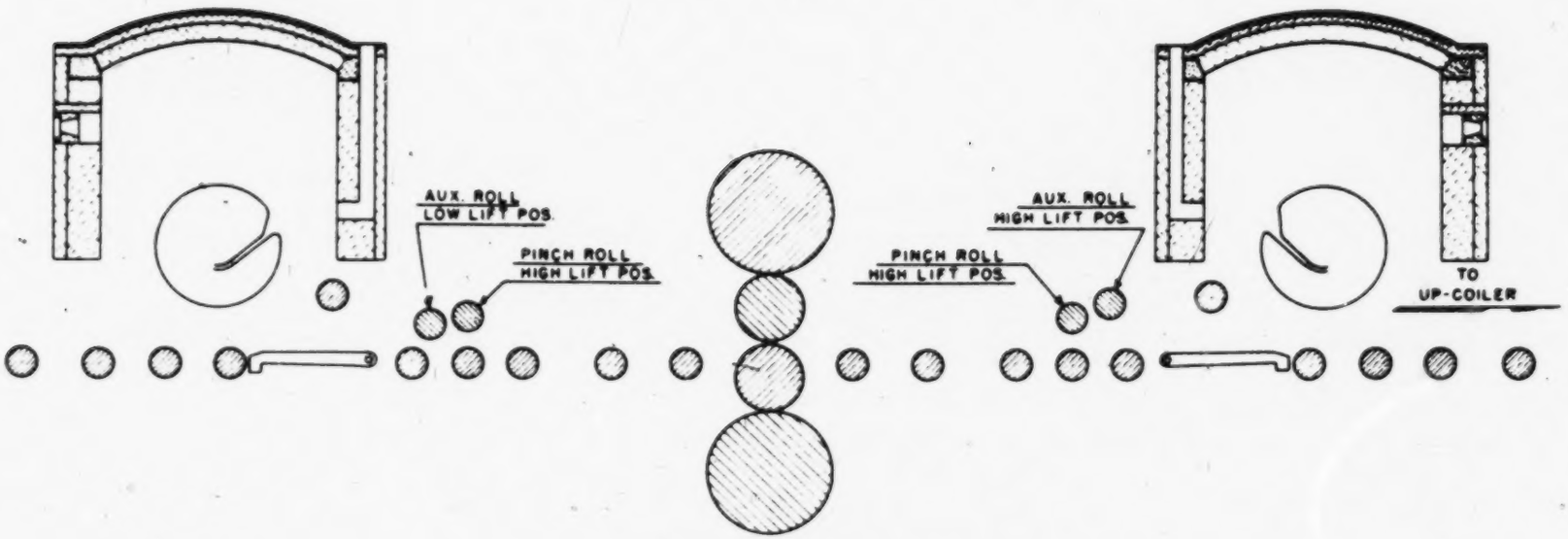
DWG. No. 22

CRUCIBLE HOT STRIP MILL

OPERATION OF MODIFIED MILL



FINAL PASS STARTED

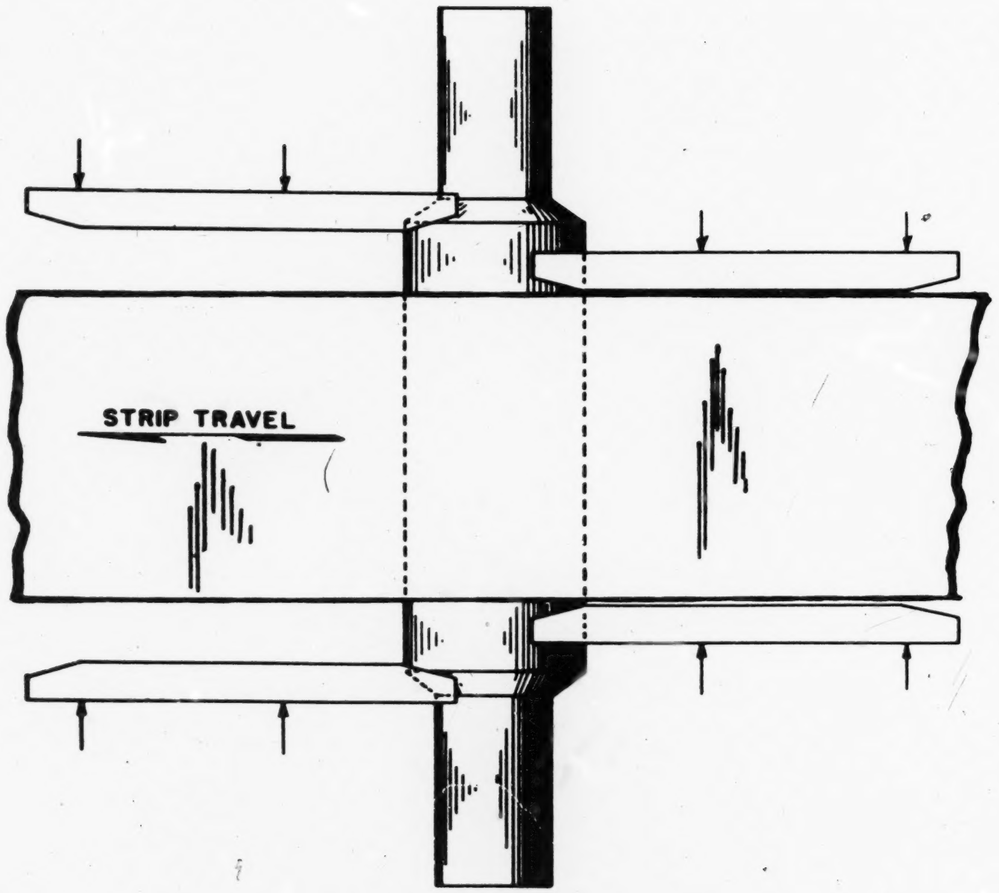


FINAL PASS DURING ROLLING

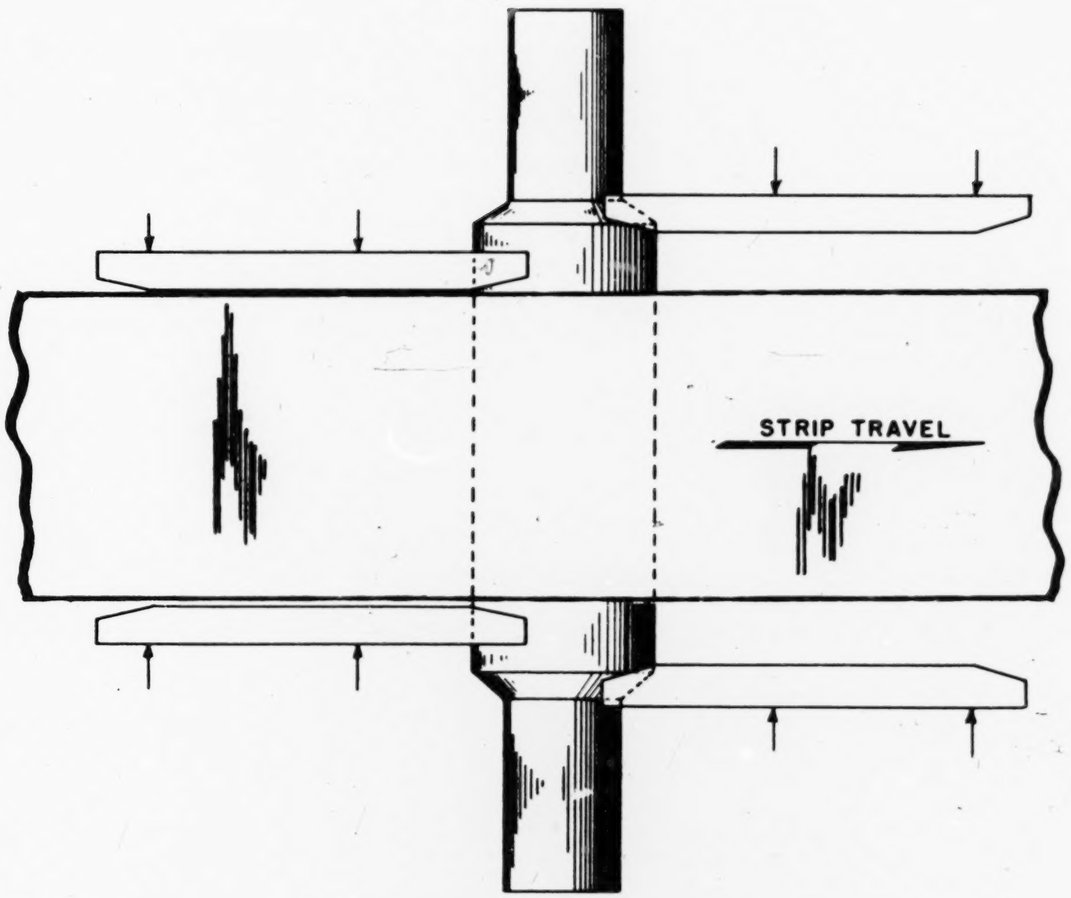
DWG. No. 23

CRUCIBLE HOT STRIP MILL

SIDE GUIDE POSITIONS DIAGRAMMATICALLY ILLUSTRATED



THREADING & RUNNING POSITIONS
TRAVEL TO LEFT



THREADING & RUNNING POSITIONS
TRAVEL TO RIGHT

Defendant's Exhibit D-4.

C. B. CUSHWA.

METHOD OF ROLLING SHEET METAL.

APPLICATION FILED AUG. 18, 1905.

904,605. Patented Nov. 24, 1908

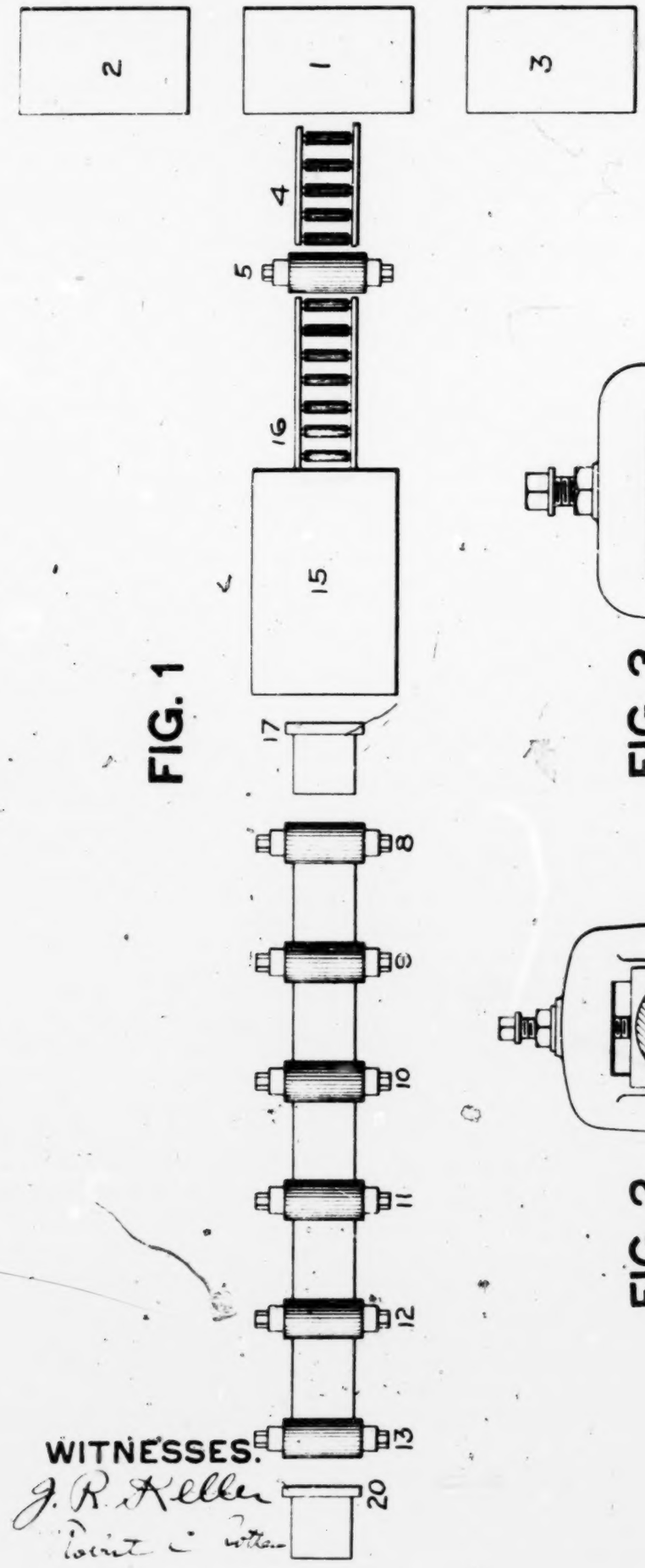


FIG. 1

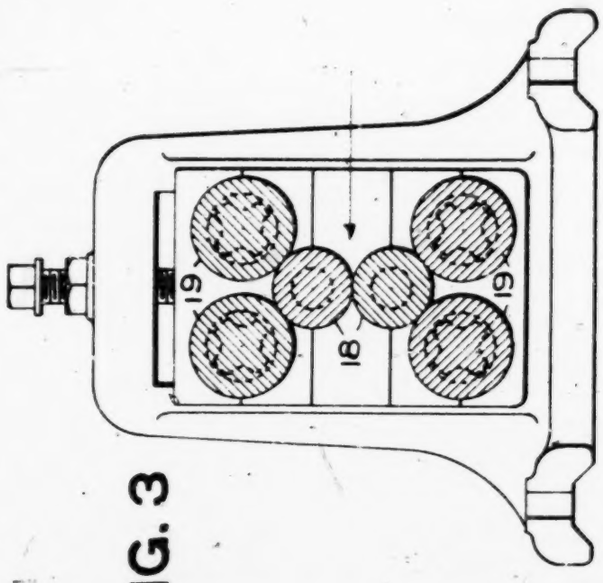


FIG. 3

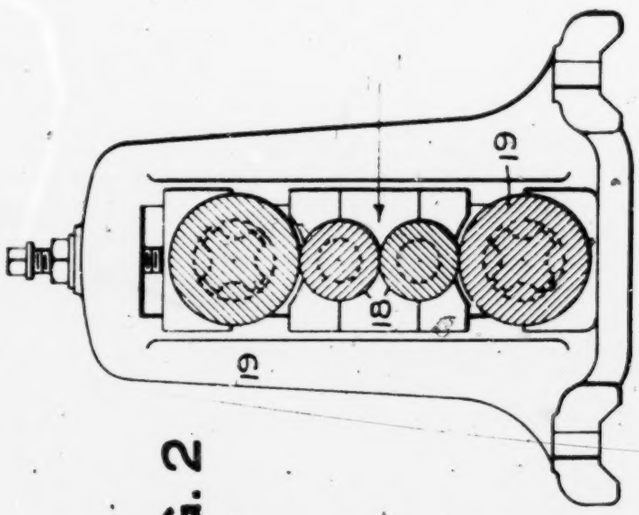


FIG. 2

WITNESSES.

J. R. Kelber

Robert C. Potter

INVENTOR.

Charles B. Cushwa

By Roy Potter & Watts

Attorneys

UNITED STATES PATENT OFFICE

CHARLES B. CUSHWA, OF YOUNGSTOWN, OHIO.

METHOD OF ROLLING SHEET METAL.

No. 904,605. Specification of Letters Patent. Patented Nov. 24, 1908.

Application filed August 18, 1905. Serial No. 274,726.

To all whom it may concern:

Be it known that I, CHARLES B. CUSHWA, a resident of Youngstown, in the county of Mahoning and State of Ohio, have invented a new and useful Improvement in Methods of Rolling Sheet Metal; and I do hereby declare the following to be a full, clear, and exact description thereof.

My invention relates to a method of rolling metal in the form of thin sheets or strips, and its object is to provide a method whereby the many reheatings and the many manipulations and handlings of the metal employed in ordinary processes are dispensed with, thereby greatly reducing the cost of production; one wherein the amount of scrap produced is very largely reduced, and one wherein both faces of the sheet are subjected to the action of rolls, thus giving a bright and smooth surface on both sides.

The most commonly employed process of producing sheet and similar metal is to start with a sheet bar which is about $\frac{3}{8}$ to $\frac{3}{4}$ of an inch in thickness, and 5 to 8 inches wide, and of a length approximately equal to the width of sheets to be formed. These sheet bars are heated and reduced in breaking down rolls, which are ordinarily 2-high rolls through which the plate is fed a number of times. Two or more sheets thus formed are then piled one on the other and rolled down to about 18 to 20 gage. These sheets are then separated or opened up and again piled and reheated to a good rolling temperature and then further reduced. For the coarser gages this is generally sufficient, but for the finer gages the packs are doubled one or more times, again reheated and further reduced. This old hand process requires a large amount of labor and repeated reheatings, thus adding considerably to the cost of production. It also results in the production of a large amount of scrap, this being due to the fact that when piled the sheets do not stay in exact position but slip sidewise or endwise and thus result in producing edge portions which are of unequal thickness. If the edges are very thin they do not elongate in the further reduction but are caused to crack. All of these cracked and unequal edges must be sheared off. Furthermore, it is not possible to handle long packs by hand, and owing to the tendency of the sheets to separate and slip they are rolled mostly in lengths from 8 to 10 feet long. At each end of these sheets there is from 6 to 10 inches of scrap which must be sheared off. Furthermore, in rolling the sheets in packs only one side of the two outside sheets of the pack are subjected to the action of the rolls. These receive a bright and smooth finish. All of the other faces being in contact have a rough, duller finish, so that it is necessary to finish by cold rolling the sheets separately.

It has been proposed to roll sheets by running the packs or piles through continuous or tandem mills. This has the advantage over the old hand process of reducing the amount of labor and the number of reheatings. The sheets, however, are packed or piled and therefore the amount of scrap produced is equal to that of the old hand process, and the sheets also must be cold rolled in order to finish the same.

The object of my invention is a method of rolling sheets, strips and other thin metal, in which the above defects and objections are overcome.

It consists, generally stated, in starting with an ingot, billet or slab, roughing the same down to approximately $\frac{1}{2}$ inch or less in thickness, and then while still at the same heat passing the plates so produced singly through tandem mills consisting of a sufficient number of stands of small sized rolls to reduce the same to finished gage. As a consequence labor and reheatings are largely overcome, both faces of the sheet are of the same bright, smooth finish, thus dispensing with cold rolling to finish, and the finished sheet is of very long length, producing scrap only at its two ends, and the side edges being of the same thickness as the body and not cracked, so that only very little metal need be sheared off and the amount of scrap is reduced to a minimum.

In the accompanying drawing Figure 1 shows in diagram apparatus suitable for carrying out my process; and Figs. 2 and 3 are sectional views of suitable rolls for the tandem mill.

1, 2 and 3 represent suitable heating furnaces wherein the ingot, billet or slab is heated to a suitable rolling temperature. From these furnaces the heated ingot, billet or slab is transferred to the feed table 4 of the roughing down mill 5. The latter can be either a 2-high reversing mill or a 3-high mill. The heated ingot, billet or slab is

passed back and forth through the mill 5 in well understood manner until it is reduced to a plate of approximately the width of the sheet to be formed and from about one quarter to a half inch thick.

The ingot, billet or slab is much cheaper to produce than the sheet bars heretofore necessary. Furthermore, it can be roughed to the gage specified at a single heat, and its gage is still such that the plate holds sufficient heat to enable it to be reduced to finished gage in the tandem or continuous mills represented by the rolls 8, 9, 10, 11, 12 and 13. To guard against delays on these finishing rolls I prefer to run the plate as it emerges from the mill 5 into a furnace 15, suitable live rolls 16 being employed to convey the plate through said furnace. In this furnace the plate, if delayed, is maintained at a good rolling heat, even though it be delayed a considerable time before entering the finishing mill. A shear 17 is provided for clipping off the front ragged end of the plate before entering the finishing mill. The finishing mill is shown as composed of six stands of rolls arranged in tandem, but the number thereof may be greater or less than this number, and in any event will be sufficient to reduce the plate to the finished gage.

The tandem mills are of the form shown in Figs. 2 and 3 in which the reducing rolls 18 are of comparatively small diameter. In order to give these small sized rolls sufficient stiffness each is backed by one or two large rolls 19, Fig. 2 showing one such backing roll and Fig. 3 showing two. The small sized rolls 18 have only a small area of contact with the metal being reduced, hence they press more deeply into, and more rapidly reduce or stretch the metal, than do the large diameter rolls usually employed in sheet mills. The small area of contact between such rolls and the plate also has the effect of reducing the amount of heat absorbed from the plate so that the latter is maintained at a better rolling heat than if larger rolls were used. The plate, after being roughed down is still very close to the initial heat of the blank, that is, a good bright red heat, and the further reduction thereof in the tandem mill described is effected so rapidly and with such a small absorption of heat by the rolls, that the plate reaches practically the thinnest gages before the temperature falls below a dull red.

By my process I start with ingots, billets or slabs, which are cheap compared to the usual plate bar, and reduce them to finished gage and without piling or folding the partially reduced sheets, and substantially at the initial heat. The plate emerging from the finishing rolls is very long and its edges are only slightly irregular. As a consequence the amount of scrap is very small. After leaving the mill the plate is cut to finished size by shears 20.

The labor necessary to carry out my process is reduced to a minimum, and as reheatings are practically dispensed with there is also a great saving of fuel. Furthermore, each sheet is finished separately so that both faces are acted on by the rolls and consequently have a bright smooth finish, thus dispensing with cold rolling to finish. As a consequence the process is very economical.

In case the metal is to be formed as strips it can be either rolled in narrow widths or else passed through suitable slitting shears after emerging from the finishing rolls.

What I claim is:

1. The method of rolling sheet metal, which consists in heating a suitable blank, and without further heating reducing the same to 20 gage United States standard, or thinner, by subjecting the same to successive rolling actions applied to small areas equally on both sides of the plate, thereby effecting the reduction at a temperature not less than a good dull red.

2. The method of rolling metal sheets, strips and the like, which consists in heating an ingot, billet, or slab, reducing the same by rolling and without further heating to a plate approximately $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, and then at the same heat reducing the same to finished gage by subjecting the same to successive rolling actions applied to small areas equally on both sides of the plate.

In testimony whereof, I, the said CHARLES B. CUSHWA have hereunto set my hand.

CHAS. B. CUSHWA.

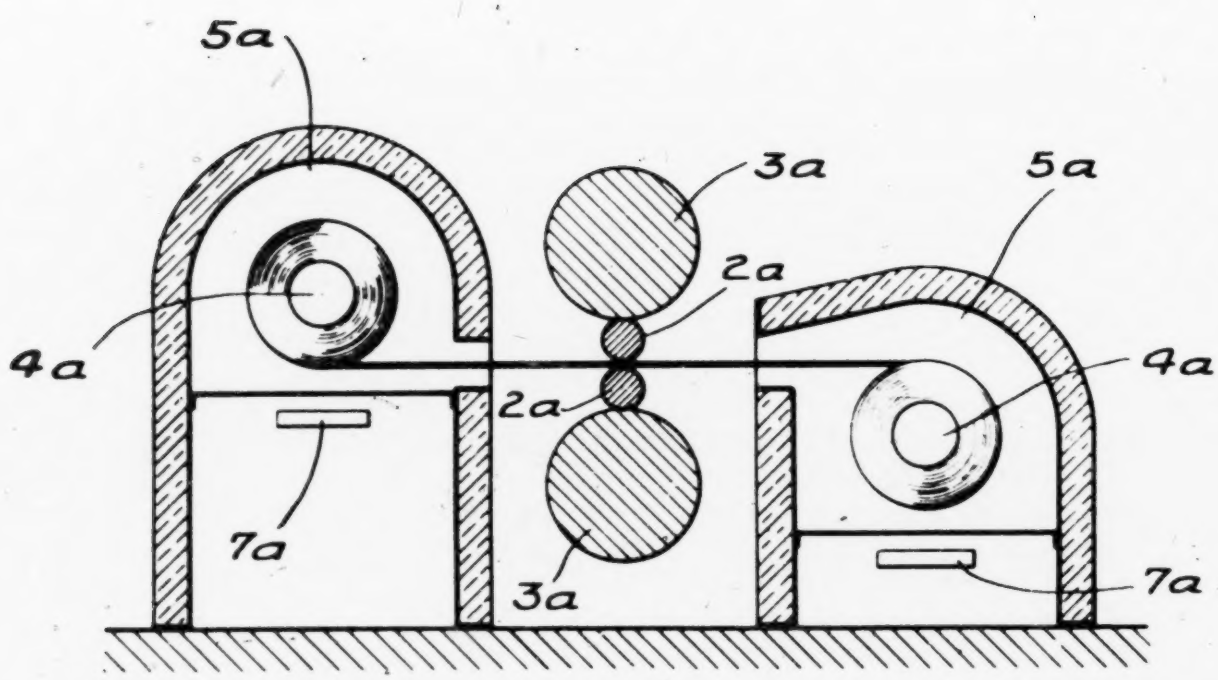
Witnesses:
F. W. WINTER,
ROBERT C. TOTTEN.

Defendant's Exhibit D-13-A.

May 10, 1932. A. P. STECKEL **1,857,670**

ROLLING METAL STRIP

Filed June 15. 1927



INVENTOR
A. P. Steckel
by his attys,
Byron, Stebbins & Pamela

Patented May 10, 1932 1,857,670

UNITED STATES PATENT OFFICE

ABRAM P. STECKEL, OF YOUNGSTOWN, OHIO, ASSIGNOR TO THE COLD METAL PROCESS COMPANY, OF YOUNGSTOWN, OHIO, A CORPORATION OF OHIO

ROLLING METAL STRIP

Application filed June 15, 1927. Serial No. 198,915.

This invention relates to the rolling of metal strip and particularly to the hot rolling thereof. The term strip is herein employed to define an extended length of metal in sheet form regardless of its width.

Metal strip is now being rolled in continuous mills, but these mills are so large and occupy so much space that a very heavy capital outlay is required. The operating cost of the continuous mill is high because of the large amount of power required.

An older method of making strip material is to employ a single reversing stand and to run the metal out on a roll table to either side of the stand. This method is undesirable because as the metal is reduced to the thinner gauges it rapidly loses heat.

I provide for subjecting a piece of heated metal to a plurality of roll passes and coiling the metal between passes. This reduces the radiating surface to a minimum and permits of rolling for long periods of time without reheating. It also makes it possible to materially reduce the cost of the installation since the long run-out tables are unnecessary. It will be understood that roll tables may be employed for effecting some of the preliminary reductions, but these will not need to be of anything like the length which would be required for the final product. I may place the coilers in heat conserving chambers, one on either side of the mill. These chambers may be arranged so as to be moved sidewise and thus permit of rolling a slab in the ordinary way down to such thickness that it can be coiled.

Another advantage of the coilers lies in the fact that they are effective for scaling the metal. I arrange the coilers so that the metal is curled first in one direction and then in the other, so that the scale is cleaned from both sides.

The accompanying figure of drawing illustrates my invention diagrammatically. It shows a reversing mill comprising a pair of working rolls 2*a*, each provided with backing up rolls 3*a*. Either the working rolls or the backing up rolls may be driven, as desired. The mill is provided with the usual screw-downs so that successive reductions may be made.

Coilers 4*a* are provided on either side of the mill, these being arranged to reel or to pay out material depending on which way the mill is running. Each coiler is motor driven and may be operated at such a rate as to maintain the delivered strip under tension. Each coiler is contained in a heat conserving chamber 5*a* having suitable doors, not shown, to permit of removing a coil of material. Each chamber is provided with heating means 7*a* to maintain it at the proper temperature. Once the chambers are hot and the device is in operation, very little heat will be required beyond that supplied by the metal itself.

In operation a heated slab will be rolled in the ordinary way until it is thin enough to coil. The coiled material is supplied to the mill and fed from one reel through the mill and thence to the other reel. On the next succeeding pass the operation will be reversed, the paid out material being fed back through the mill to the first coiler. The heat loss will be very slight as compared with ordinary rolling practice due to the very small radiating surface presented by the coil and also due to the conservation of heat by the chamber 5*a*.

It will be noted that the material is flexed first in one direction and then in the other. This effects removal of the scale from the strip.

While I have illustrated a preferred embodiment of my invention, it will be understood that the invention is not thus limited, as it may be otherwise practiced or embodied within the scope of the following claims:—

I claim:—

1. The method of rolling metal strip which includes coiling a strip of hot metal in a heating chamber, uncoiling the same and feeding it from the chamber through a roll pass and to another heated chamber, coiling the strip therein in a direction opposite to that in which it was first coiled, and periodically reversing the direction of rolling.

2. The method of rolling metal strip which includes coiling a strip of hot metal in a heating chamber, uncoiling the same and

feeding it from the chamber through a roll pass and to another heated chamber, coiling the strip therein in a direction opposite to that in which it was first coiled, periodically reversing the direction of rolling, and maintaining the metal under tension between the rolling thereof and the coiling thereof.

3. The method of rolling strip metal which includes coiling a strip of hot metal in a heating chamber, uncoiling the same and feeding it from the chamber through a roll pass and to another heated chamber, coiling the strip therein, periodically reversing the direction of rolling so that the material is fed back and forth from one coil to another, and subjecting the material to bending in both directions so as to effect removal of scale.

In testimony whereof I have hereunto set my hand.

ABRAM P. STECKEL.

July 18, 1933. R. M. KEENEY ET AL 1,918,968

ROLLING MILL

Filed Jan. 12, 1928 3 Sheets-Sheet 1

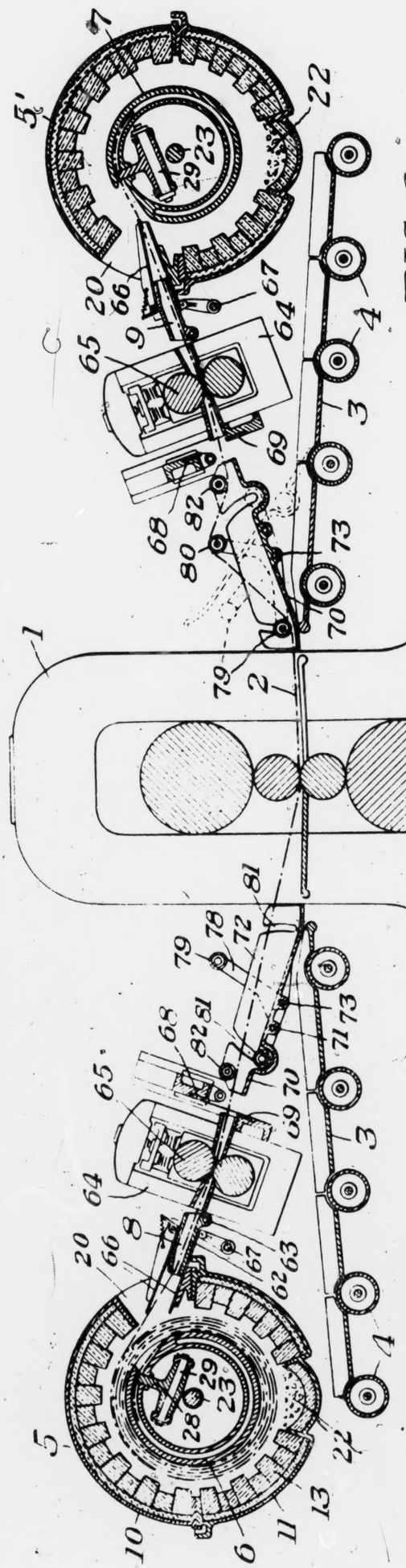


FIG. 1.

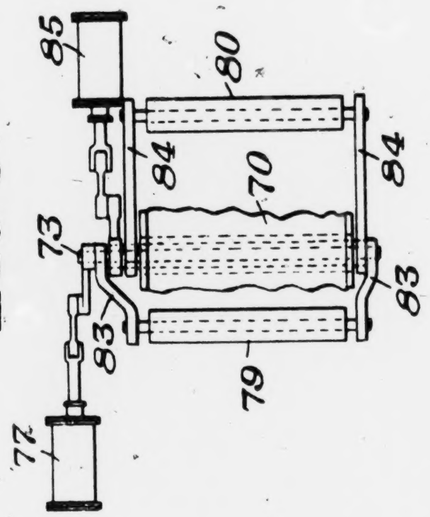


FIG. 6.

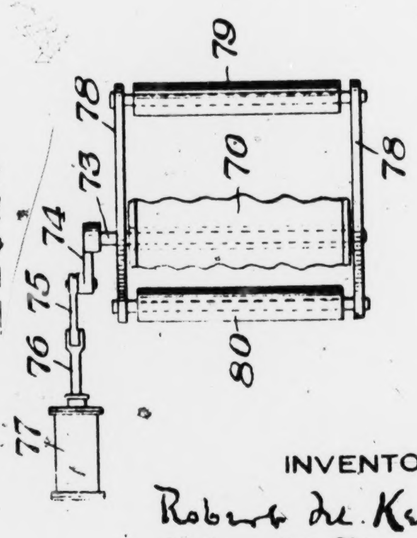


FIG. 5.

INVENTORS

Robert M. Keeney

John F. Ferm,

by Christy & Christy

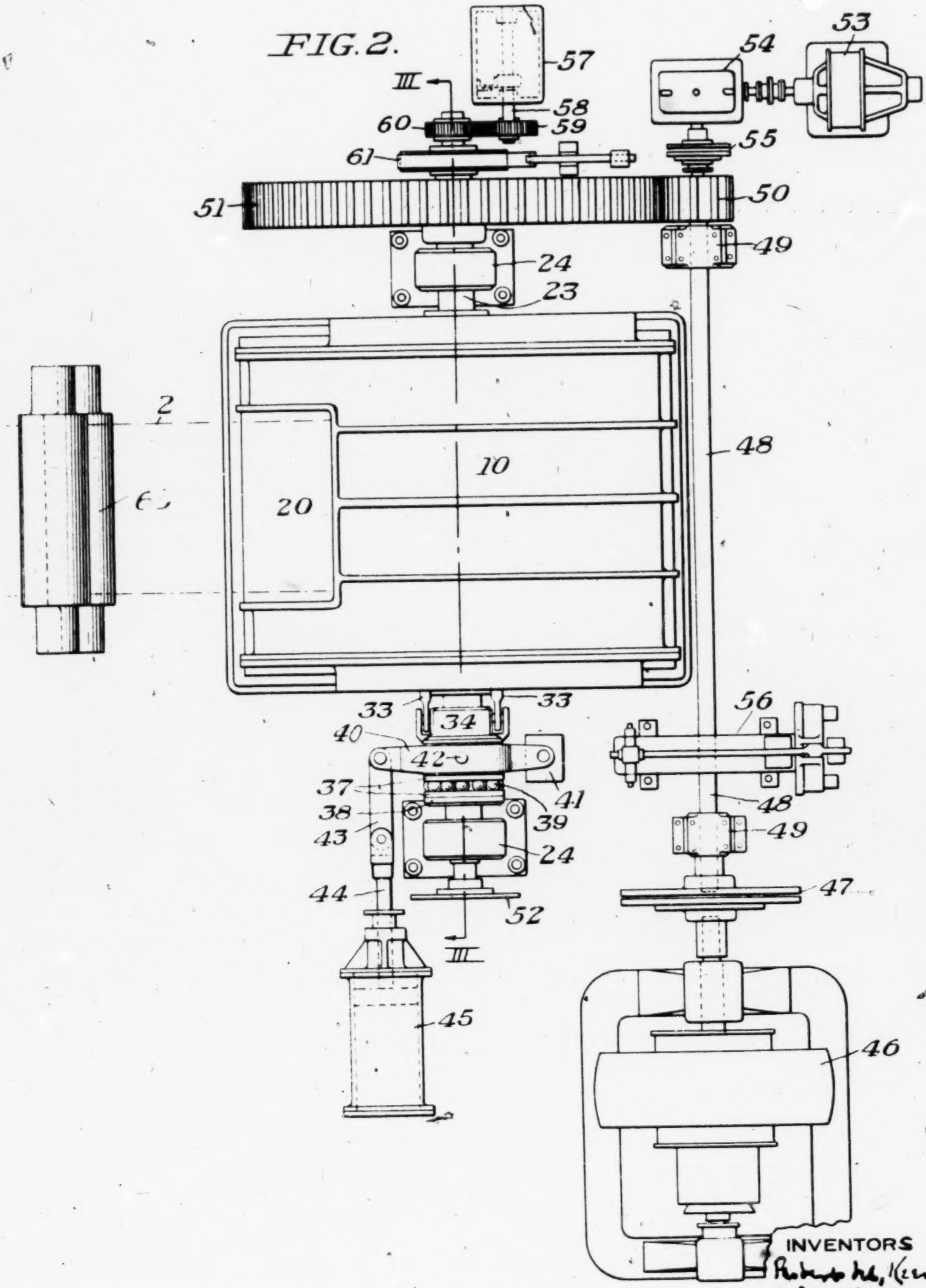
Attys.

July 18, 1933. R. M. KEENEY ET AL 1,918,968

ROLLING MILL

Filed Jan. 12, 1928 3 Sheets-Sheet 2

FIG. 2.



INVENTORS
Robert M. Keeney
John F. Irons
by Christy & Christy
Attys.

July 18, 1933. R. M. KEENEY ET AL 1,918,968

ROLLING MILL

Filed Jan. 12, 1928 3 Sheets-Sheet 3

FIG. 3.

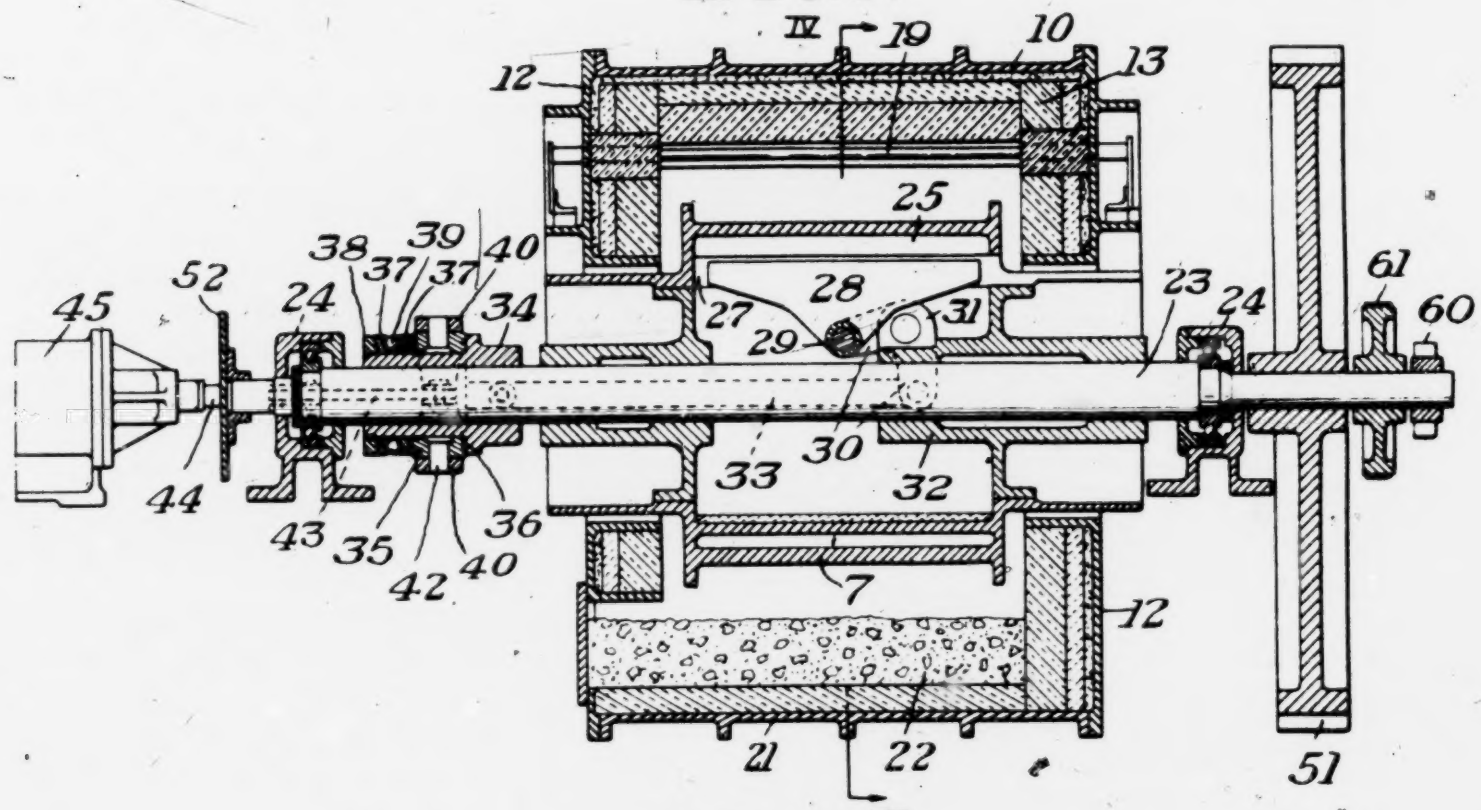
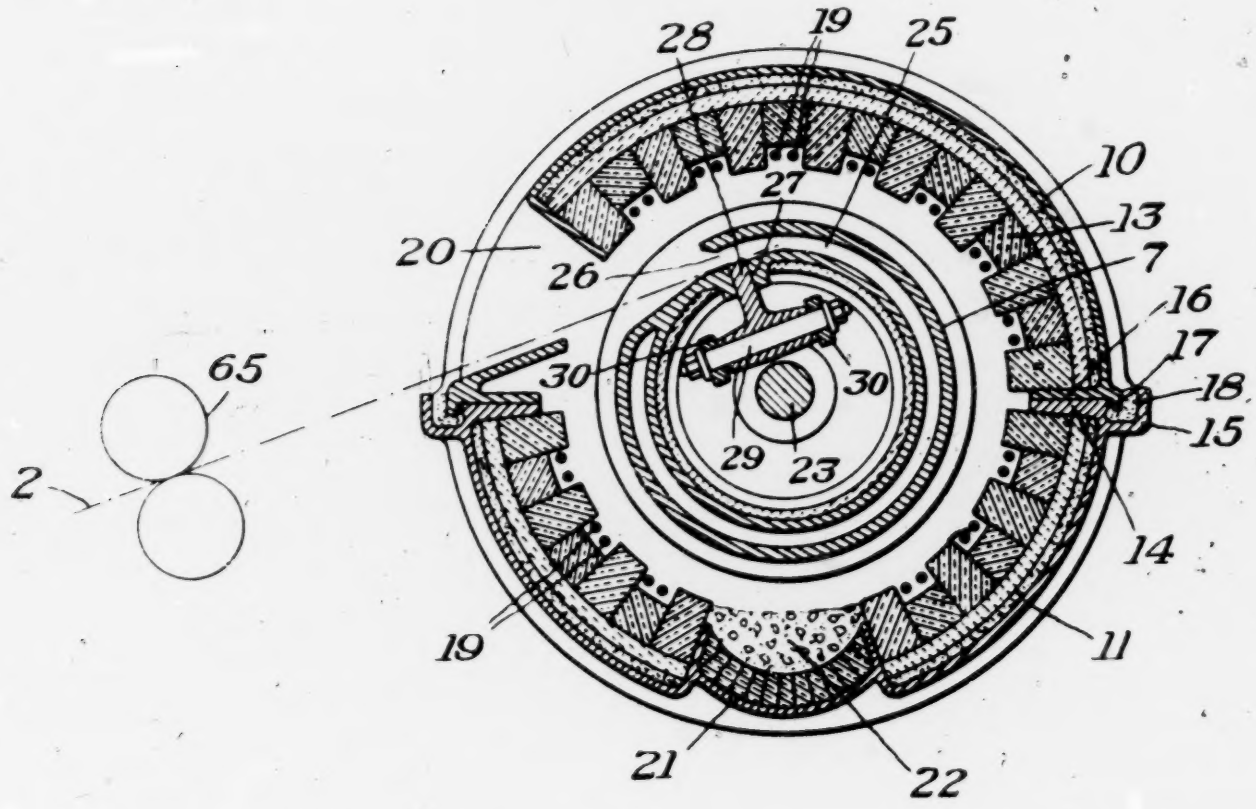


FIG. 4.



INVENTORS

Robert M. Keeney

John F. Ferree

by Christy & Christy

Attys

Patented July 18, 1933 1,918,968

UNITED STATES PATENT OFFICE

ROBERT M. KEENEY AND JOHN F. FERM, OF MIDLAND, PENNSYLVANIA

ROLLING MILL

Application filed January 12, 1928. Serial No. 246,181.

This invention relates to the rolling of metal in strip-like form and while, as herein described, it is particularly applicable to the hot rolling of iron or steel strips or strip sheets of light gauge and great length, it is also applicable in certain of its aspects to the cold rolling of metal in strip-like form. In the manufacture of sheet steel it has been proposed, and in some cases practiced, to supersede the old and common methods of finishing comparatively short lengths of rough-rolled sheets by matching and doubling, by rolling wide and long sheets in a continuous mill. Not only does this require a mill of great length and very accurate relative adjustment of the passes through the successive stands of rolls, but the strip in the process of reduction and elongation loses heat so rapidly that the manufacture of the lighter gauges of sheets in this way has been economically impracticable. It is the primary object of the present invention to provide means whereby long and thin strips can be heated effectively and economically during the process of rolling, and therefore can be reduced to any thinness attainable by hot rolling, and the entire operation, after the initial roughing-down, can, if desired, be carried out in a single stand of rolls.

In the accompanying drawings Figure 1 is a view in longitudinal sectional elevation of the finishing rolls of a strip mill having combined therewith mechanism embodying the present invention. Figure 2 is a plan view of one of the coilers and its operating mechanism. Figure 3 is a section of the coiler on the line III—III of Figure 2. Figure 4 is a cross-section on the line IV—IV of Figure 3. Figures 5 and 6 show alternative means for maintaining tension upon the strip.

The stand of rolls 1 is shown only conventionally, and it will be understood that suitable means for adjustment of the rolls, and other proper accessories, will be employed. The strip being rolled is designated by the broken line 2. The usual feed-tables 3 having driven rollers 4 are shown on the opposite sides of the stand of rolls 1.

Above the tables and the roll-pass and on opposite sides of the stand of rolls 1 are suitably supported heating-furnaces or chambers 5 and 5′, within which are rotatably mounted reels or drums 6 and 7, and from which the inclined chutes 8 and 9 (to be hereinafter described) lead down to the roll-pass. As shown in Figures 3 and 4, each of the heating furnaces comprises upper and lower semi-cylindrical metallic shells 10 and 11, having closed end walls 12, and lined with refractory 13. The lower shell 11 has an inner flange portion 14 at its top and an outer cup portion 15, and the upper shell 10 has an inner flange portion 16 which rests on the flange 14, and an outer downwardly bent lip 17 which projects into the cup 15, where the joint is packed with loose refractory 18. By reason of this construction the upper half of the furnace may be lifted off the lower half by means of a hoisting crane whenever desired. The resistors 19 are suitably arranged and mounted within the heating chamber for the electrical generation of heat. The transverse opening 20 is formed in the upper shell 10 for the passage of the strip being rolled. I term each heating furnace and reel, with their accessories, collectively a coiler. A trough or basin 21 may be formed in the bottom of the lower shell 11, and be filled with a substance having a greater affinity for oxygen than has the metal strip being rolled, such as coal-dust, coke or charcoal 22, so as to protect the strip from injurious scaling.

Each reel or drum 6 and 7 is mounted upon a driving shaft 23 which projects out through suitable openings in the opposite end walls 12 of the heating chamber and is supported in bearings 24. The reel has a transverse slot 25 in its wall adapted to receive the advance end of the strip being rolled, the entrance opening 26 of which is shown in Figure 4 as standing adjacent to the opening 20 in the wall of the coiler. A second transverse slot 27 through the inner wall of the slot 25 near its entrance end connects the slot 25 with the inner open body of the reel, and in this slot 27 works the locking-bar 28, adapted when projected outwardly to bind the advance portion of the strip being rolled against the opposite wall of the slot 25 and thus lock the strip to the reel in the coiler. At its inner end

the bar 28 carries a stub shaft 29, the opposite ends of which are connected to the horizontal arms of rocking-levers 30 pivoted to small standards 31 supported on one of the hubs 32 of the reel, on opposite sides of the driving-shaft 23. The lower ends of the vertical arms of the levers 30 are connected by links 33 to the sleeve 34, which rotates with but can slide upon the shaft 23. A collar 35 is mounted upon the sleeve 34 between an inner shoulder 36 on the sleeve and the rings 37 held in place by a nut 38 screwed upon the outer end of the sleeve. Anti-friction balls 39 are interposed between the rings 37. A bifurcated lever 40, pivoted at one end to the standard 41, is connected at its central points by pins 42 to the collar 35, and at its opposite end is loosely connected by link 43 to the piston-rod 44 of the motor-cylinder 45. Thus by operating the piston in the cylinder 45, the bar 28 will be advanced and retracted to lock and release the end of the strip being rolled.

Mechanism suitable for driving the reel to wind up the strip as it comes from the rolls is also shown in Figure 2. The shaft of the motor 46 is connected by a magnetic clutch 47 to the end of the shaft 48 supported in bearings on the standards 49. At its opposite end shaft 48 has fastened to it the pinion 50 which meshes with and drives the gear wheel 51 which is fastened upon the driving-shaft 23 of the reel. At its projecting opposite end the shaft 23 may carry any suitable indicating device 52, such for example as a pointer, to show the position of the reel within the coiler, and particularly when it is in the proper position to receive the advance end of the strip being rolled, as shown in Figure 4. A separate slow drive is employed for turning the empty reel to the strip-receiving position shown in Figure 4, after the motor has been stopped and the magnetic clutch 47 (which is in the motor-operating circuit) has been opened. A separate motor 53 operates a worm and worm-wheel in the casing 54, the worm-wheel carrying a short shaft connected by a magnetic clutch 55 with the end of the shaft 48, as also shown in Figure 2.

In the unwinding of the reel 6 or 7, when the circuit of motor 46 will be broken and the clutch 47 open, it is desirable that the reverse rotation of the reel shall be stopped (and the trailing end of the strip be released) shortly before the strip is wholly withdrawn from the coiler. For that purpose we provide a magnetic brake 56 for the shaft 48, the operation of the brake being controlled by a limit switch in the box 57, and the switch being operated by a shaft 58 having a pinion 59 meshing with a pinion 60 on the end of the reel-shaft 23. Electrical apparatus of this character is well known to those skilled in the art, and detailed description of any of several forms which may be used is therefore unnecessary. The switch is so organized that it will cause the brake 56 to act upon the shaft 48 preferably when the reel has still one complete unwinding revolution to make, and we calculate that the reel will be completely stopped in a half of a revolution more. The trailing end of the strip having been by that time released by withdrawal of the bar 28, the balance of the strip will be free to be drawn out of the coiler. The brake 56 will then be opened and the motor 53 operated to turn the reel to the strip-receiving position shown in Figure 4.

To act as a drag upon the reel during unwinding we provide a band-brake 61 of common form for the shaft 23, having its free end counterweighted, so as to operate only when the shaft is turning in the unwinding direction. This brake is shown in Figures 2 and 3.

At the top of each of the chutes 8 and 9 there is arranged a guide comprising a rear section 62 pivoted at 63 to a bracket or brackets on the housing 64 of pinch-rolls 65 to be mentioned presently and resting upon the lower lip of the entrance 20 into the coiler, and an outer telescopic section 66 which is connected to a rock-shaft 67, and may be moved forwardly and backwardly by turning the rock-shaft by any suitable means. Thus the tip of the section 66 may be projected in close to the reel, as shown at the right-hand side of Figure 1, or it may be drawn back out of the way of the coils on the reel, as shown at the left-hand side.

The pinch-rolls 65, adjustably mounted in the housings 64, are located in the chutes 8 and 9 to feed the strip alternately to the coiler and back to the stand of rolls 1. These pinch-rolls may be driven by any suitable mechanism, but preferably by an electric motor, including in the motor-operating circuit a magnetic clutch operating in the same way as the clutch 47. Adjacent to and immediately below the pinch-rolls is a shear comprising a movable blade 68 and a fixed blade 69.

Below the shear and extending into proximity to the stand of rolls 1 each of the chutes 8 and 9 has a tilting section 70 centrally mounted upon a rock-shaft 71. This tilting section has a floor and preferably opposite side walls 72. The tilting sections are provided so that they may be swung to a horizontal position, on one side of the rolls 1 to admit the strip coming from the roughing rolls of the mill, and on the other side to deliver the finished strip. Or if desired both sections may be swung out of the way and the strip be given one or more passes through the rolls 1 before it enters the chutes and coilers. Also by tilting either section to the position shown in dotted lines at the right-hand side of Figure 1, any crop ends cut off by the shears can be delivered upon the roller

table 3 and disposed of without delaying the operation of the mill.

Means are provided for maintaining tension upon the strip in case it shall loop up between the rolls 1 and the pinch-rolls. Each tilting section carries beneath its floor a transverse rock-shaft 73, operated by a crank 74 at one end, which is connected by a link 75 with the piston-rod 76 of a fluid-pressure cylinder 77, as shown in Figure 5. Adjacent to the opposite ends of the shaft 73 are fastened the bent arms 78 carrying in their ends, respectively, the hubs of rollers 79 and 80, slots 81 being cut in the opposite side walls 72 to allow the passage of the hubs of the rollers as the arms 78 are rocked by means of the described connections. In the operation of the mill the strip on each side of the rolls 1 will pass under the roller 79 and over the roller 80. Tension is maintained yieldingly upon the looped strip, as shown in Figure 1, by means of the fluid-pressure cylinders, and the size of the loop aids the operator in adjusting the speed of rotation of the reel in the coiler to the speed of the reducing rolls. A bearing roller 82 is journaled in the opposite side walls 72 to maintain tension upon the looped strip, if necessary, on the upper side of the roller 80. If desired, the rollers 79 and 80 may be operated independently of each other, as shown in Figure 6. In such case the rollers 79 and 80 are mounted in the ends of independent arms, the arms 83 of the roller 79 being secured to the shaft 73 and operated by the cylinder 77 as in Figure 5, while the roller 80 is mounted in the ends of arms 84 fastened to a sleeve which surrounds the shaft 73, and which is connected to a second fluid-pressure cylinder 85.

In operation, assuming that the table 3 at the right-hand side of Figure 1 leads from the roughing mill, the roughed-down strip will be carried on this table into and through the initial pass between the reducing rolls 1, which also act to feed the strip up the chute at the left and between the pinch-rolls, which are being driven at that time and which feed the strip on into the coiler, the guide 62, 66 being in advanced position to direct the leading end of the strip into the slot 25 in the reel. As soon as the leading end of the strip enters the slot 25 it is locked by the bar 28, and the coiler-motor is started and the strip is wound on the reel, the pinch-roll motor being stopped and the driving-shaft disconnected by opening of its magnetic clutch, so that during the winding operation the pinch-rolls act as idle guide rollers. If during the rolling and winding operation the strip should loop up between the reducing rolls and the pinch-rolls, fluid pressure will be admitted to the cylinder 77 to maintain the proper yielding tension upon the strip by means of the roller 80 and the opposite flanking rollers 79 and 82, while the operator synchronizes as nearly as may be the winding speed with the speed of the reducing rolls. As soon as the trailing end of the strip passes the reducing rolls and before it reaches the pinch-rolls, the reel in the coiler is stopped and its motor disconnected from the drive shaft. The reducing rolls are then adjusted and started in the opposite direction, and the pinch-rolls are then driven in the opposite direction to feed the strip back through the reducing rolls, whence it goes to the coiler 5′ at the right-hand side of Figure 1, and is wound upon the reel 7 in the same manner as already described. During this reducing operation the pinch-rolls at the left turn idly, and the reducing rolls unwind the strip, the unwinding speed of the reel 6 being controlled by the drag-brake 61. When the last unwinding revolution of the reel 6 is reached, the locking-bar 28 is retracted and the brake 56 is automatically applied to the shaft 48. Thus the reel 6 is stopped, and the reducing rolls draw out the unlocked trailing end of the strip. Then the brake on the shaft 48 is released and the reel 6 is turned to receiving position by the motor 53. The strip may be given as many passes through the reducing rolls as may be desired, the rolls being adjusted between reductions by any of the well-known means, and since the strip is being repeatedly heated in the coilers, its proper rolling temperature will be maintained and it can be reduced to any thinness practicable by hot rolling. And since the strip while coiled loses its heat comparatively slowly, under some conditions the reducing operation may be performed without supplying heat to the coilers.

In efforts to roll single lengths of wide, very thin strip difficulties have been encountered in properly entering and delivering the strip into and from the reducing rolls. In the practice of the present invention such difficulties can be eliminated by making the final reducing passes while retaining the opposite ends of the strip in the opposite coilers, or at least back of the pinch-rolls, and shearing off the short unreduced opposite end portions, which will be only a negligible part of a long strip. In such case, after the final pass from left to right, the reducing rolls can be opened and the unreduced end drawn through and sheared off, and the finished strip then fed down onto the left-hand delivery-table 3 and the opposite end sheared off.

It will be noticed also that if the tilting sections of the chutes are turned to horizontal position, the mill with the opposite tables 3 may be used for rough rolling in the usual manner.

It is obvious that the coilers may be heated by the combustion of fuel instead of by electrically generated heat, and it is also the fact that many changes may be made in the structure and the various operating means here-

in shown and described without substantial departure from the invention as defined in the respective appended claims.

In the introductory part of this specification we have described this invention as particularly applicable to the hot rolling of iron or steel strips or strip sheets of light gauge and of great length. Heretofore in the art the term "strip" has been used to designate a long, thin piece of metal which is comparatively narrow, say of a maximum width of sixteen inches. Our invention is not limited to the manufacture of such pieces, but it is the intention to cover in the appended claims the manufacture of long, thin pieces of metal of any practicable width, and designated by us generally (whether narrow or wide) as thin metal strips.

We claim as our invention:

1. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls, of a pair of heating-chambers arranged one on each side of said rolls each having an opening for the passage of strip, means for supplying heat to each chamber, a winding-reel mounted in each chamber, means for guiding the strip from the rolls to each reel, means connected to each reel for alternately securing and releasing the strip, and means for operating each reel and winding the strip thereon.

2. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls, of a pair of heating-chambers arranged one on each side of said rolls each having an opening for the passage of the strip, means for supplying heat to each chamber, a winding-reel mounted in each chamber, means for guiding the strip from the rolls to each reel, means for securing the strip to each reel, means for operating each reel and winding the strip thereon, and means for returning the strip from each reel to the rolls.

3. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls, of a winding-reel adapted to receive the strip from the rolls, means for securing the strip to the reel, means for operating the reel and winding the strip thereon, and yielding means for exerting tension upon the strip between the rolls and the reel.

4. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls and mill tables arranged on opposite sides of said rolls, of a pair of winding-reels arranged one on each side of said rolls and above said tables, and chutes leading from said rolls to said reels, each of said chutes having a movable lower section.

5. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls, of a winding-reel adapted to receive the strip from the rolls, a guide for the strip adjacent to the reel, and means for moving the guide to and away from the reel.

6. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls, of a winding-reel adapted to receive the strip from the rolls, means for securing the strip to the reel, means for operating the reel and winding the strip thereon, and means for exerting tension upon the strip between the rolls and the reel, said tension-exerting means comprising a pair of spaced shiftable rollers adapted to bear one upon each face of the strip and fluid-pressure means for shifting said rollers.

7. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls, of a winding reel having an orifice adapted to receive the advance end of a strip delivered from the rolls, a movable locking-member adapted to lock the strip against the wall of the orifice, means for operating the locking-member, and means for operating the reel and winding the strip thereon.

8. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls, of a winding-reel adapted to receive the strip from the rolls, means for securing the strip to the reel, a motor detachably connected to the reel for rotating the reel and causing it to wind up the strip, means for disconnecting the motor, means for returning the strip to the rolls and thereby causing reverse rotation of the reel, and means for automatically stopping such reverse rotation at a predetermined point.

9. In a rolling-mill for the manufacture of hot-rolled thin metal strips, the combination with reducing rolls, of a winding-reel having a strip-receiving orifice adapted to receive the strip from the rolls and means for securing the strip to the reel, a guide for the strip adjacent to the reel, a motor detachably connected to the reel for rotating the reel and causing it to wind up the strip, means for disconnecting the motor, means for returning the strip to the rolls and thereby causing reverse rotation of the reel, means for stopping such reverse rotation, and a second motor for moving the reel to strip-receiving position with said orifice in alignment with said guide.

10. In a rolling mill for the manufacture of hot rolled thin metal strips, the combination with reducing rolls and mill tables arranged on opposite sides of said rolls, of a pair of winding reels arranged one on each side of said rolls and above said tables, and chutes leading from said rolls to said reels, said chutes being movable at least in part so as to lie clear of material on said mill tables.

11. In combination with a mill, a mill table on either side of the mill arranged to support material while the same is rolled back and

forth through the mill, means for effecting coiling of the material on either side of the mill as it issues therefrom, and pinch rolls for engaging the issuing material prior to the coiling thereof, the pinch rolls being so arranged as to be out of the way of material rolled back and forth on the mill tables.

12. In the method of rolling in a mill, the steps consisting in supplying a generally flat piece of material, rolling the same back and forth in the mill while it is in substantially flat form, continuing the rolling back and forth in the same mill and alternately coiling and uncoiling the rolled material.

13. In the method of rolling strip material in a mill, the steps consisting in rolling material back and forth while in substantially flat condition, and, after it has reached a desired thinness, rolling it back and forth in the same mill to effect a further reduction and coiling the same after each pass.

14. In the method of rolling in a mill, the steps consisting in rolling the material back and forth, engaging the surfaces of the issuing material after each pass so as to feed the same forward and exert a tension thereon, coiling the material beyond the point of engagement by the pinch rolls, and uncoiling and feeding it back through the pinch rolls to the mill.

15. In the method of rolling in a mill, the steps consisting in rolling material back and forth in substantially the flat state, and thereafter continuing the rolling by successive passes in said mill but diverting the material from its path and effecting coiling of the same.

16. In combination with a mill, a table on either side of the mill of such character as to support a flat piece of material from the time of issuance thereof from between the rolls of the mill until it has been fed back through the mill, the tables being effective for supporting the material while it is relatively thick and in an uncoiled state, and coilers adapted for automatically reeling and paying out material rolled on the mill when the same has been thinned and elongated.

17. In combination with a mill, a table on either side of the mill of such character as to support a flat piece of material from the time of issuance thereof from between the rolls of the mill until it has been fed back through the mill, the tables being effective for supporting the material while it is relatively thick and in an uncoiled state, coilers adapted for automatically reeling and paying out material rolled on the mill when the same has been thinned and elongated, and means for maintaining the coiled material at elevated temperature.

18. In combination with a mill for rolling material first in one direction and then in the other, a roll table on either side of the mill whereby a piece in flat or slab-like condition may be rolled back and forth and supported substantially in its entirety on the tables during such rolling, and coilers adapted for automatically reeling and paying out material rolled on the mill after the same has been thinned and elongated.

19. In combination with a mill for rolling material first in one direction and then in the other, a roll table on either side of the mill whereby a piece in flat or slab-like condition may be rolled back and forth and supported substantially in its entirety on the tables during such rolling, coilers adapted for automatically reeling and paying out material rolled on the mill after the same has been thinned and elongated, and means for guiding the material to the coilers.

20. In combination with a mill for rolling material first in one direction and then in the other, a mill table on either side of the mill arranged to support material in a flat condition while the same is rolled back and forth through the mill, means for effecting coiling of material on either side of the mill as it issues therefrom, and means for diverting material from the plane of a mill table into a path to be engaged by the coiler.

21. In combination with a mill for rolling material first in one direction and then in the other, a mill table on either side of the mill arranged to support material in a flat condition while the same is rolled back and forth through the mill, means for effecting coiling of material on either side of the mill as it issues therefrom, pinch rolls for engaging the issuing material prior to the coiling thereof, and means for diverting material from the plane of a mill table into a path to be engaged by the coiler.

22. In combination with a rolling mill, a mill table on either side of the mill arranged to support material while the same is rolled back and forth through the mill in the flat state, means for deflecting material upwardly from the plane of the tables, and a coiler on either side of the mill for engaging and coiling the deflected material.

23. In combination with a rolling mill, a mill table on either side of the mill arranged to support material while the same is rolled back and forth through the mill in the flat state, means for deflecting material upwardly from the plane of the tables, a coiler on either side of the mill for engaging and coiling the deflected material, and chambers above the plane of the tables containing the coilers, the chambers being arranged to prevent loss of heat of the coiled material.

24. In a method of rolling strip in a mill adapted to roll material first in one direction and then in the other and having pinch rolls on the opposite sides thereof, the steps including reducing the strip in the mill and passing it through the pinch rolls on the exit side of the mill and coiling the material be-

yond said pinch rolls, continuing the rolling until the trailing end of the strip passes through the mill rolls, stopping the material, and utilizing said pinch rolls to feed the material back to the mill.

25. In a method of rolling strip in a mill adapted to roll material first in one direction and then in the other and having pinch rolls on opposite sides thereof, the steps including driving the pinch rolls on the entering side of the mill to feed the leading end of a strip toward and through the mill and through the pinch rolls on the exit side, coiling the material beyond the last-mentioned pinch rolls, continuing the rolling until the trailing end of the strip passes through the mill rolls, and reversing the last-mentioned pinch rolls to feed the strip back toward and through the mill.

26. In a method of rolling strip in a mill adapted to roll material first in one direction and then in the other, and having pinch rolls on opposite sides thereof, the steps including reducing the strip in the mill, passing the leading end of the strip through the pinch rolls on the exit side thereof and coiling the material beyond said pinch rolls, continuing the rolling until the trailing end of the strip passes through the mill rolls, stopping the material before the trailing end has passed through the pinch rolls, and utilizing the pinch rolls for feeding such end of the strip back to the mill.

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Oct. 16, 1934. A. P. STECKEL 1,977,214

METHOD AND APPARATUS FOR HOT ROLLING STRIP METAL

Filed May 4, 1931 7 Sheets-Sheet 1

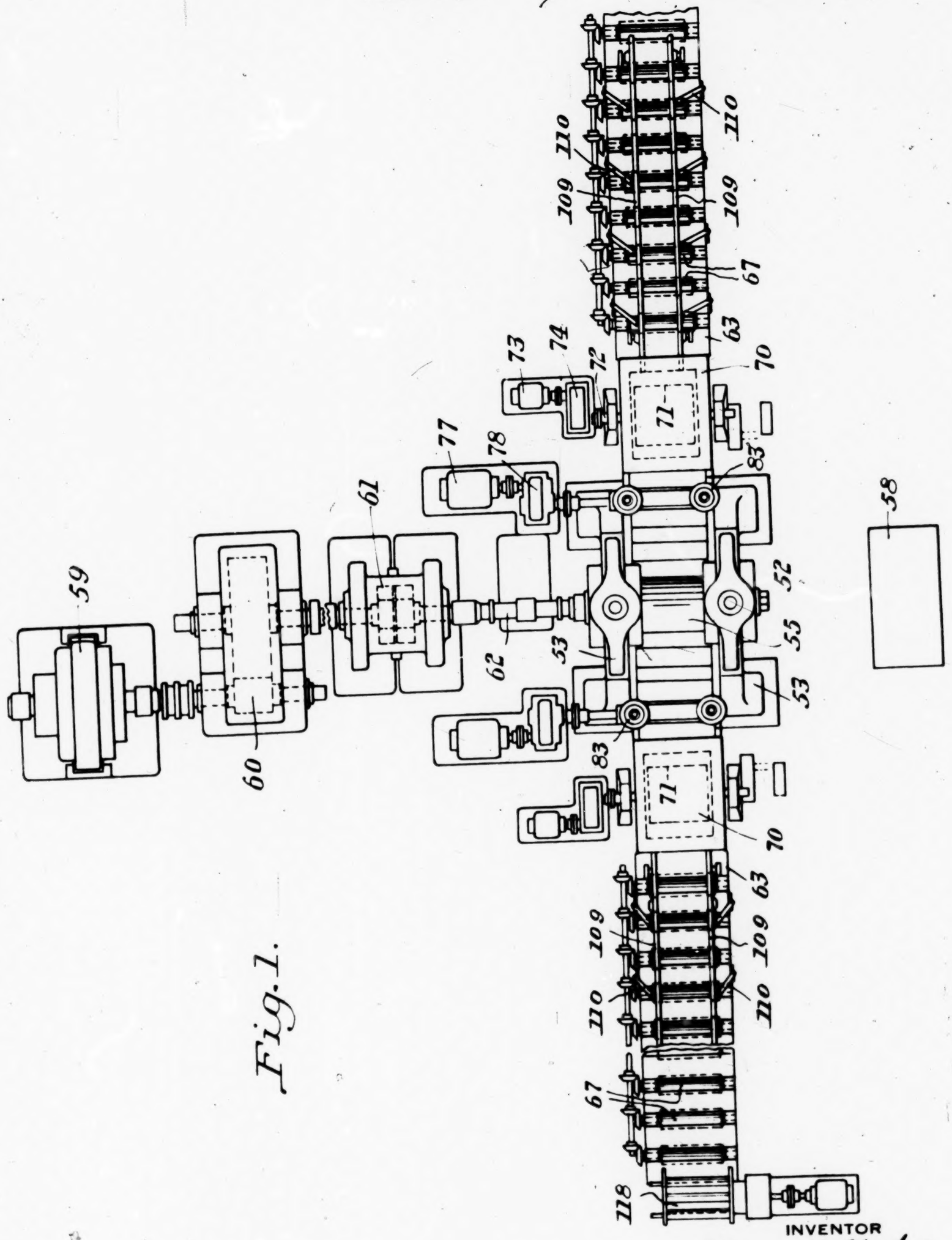


Fig. 1.

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METHOD AND APPARATUS FOR HOT ROLLING STRIP METAL

Filed May 4, 1931 7 Sheets-Sheet 2

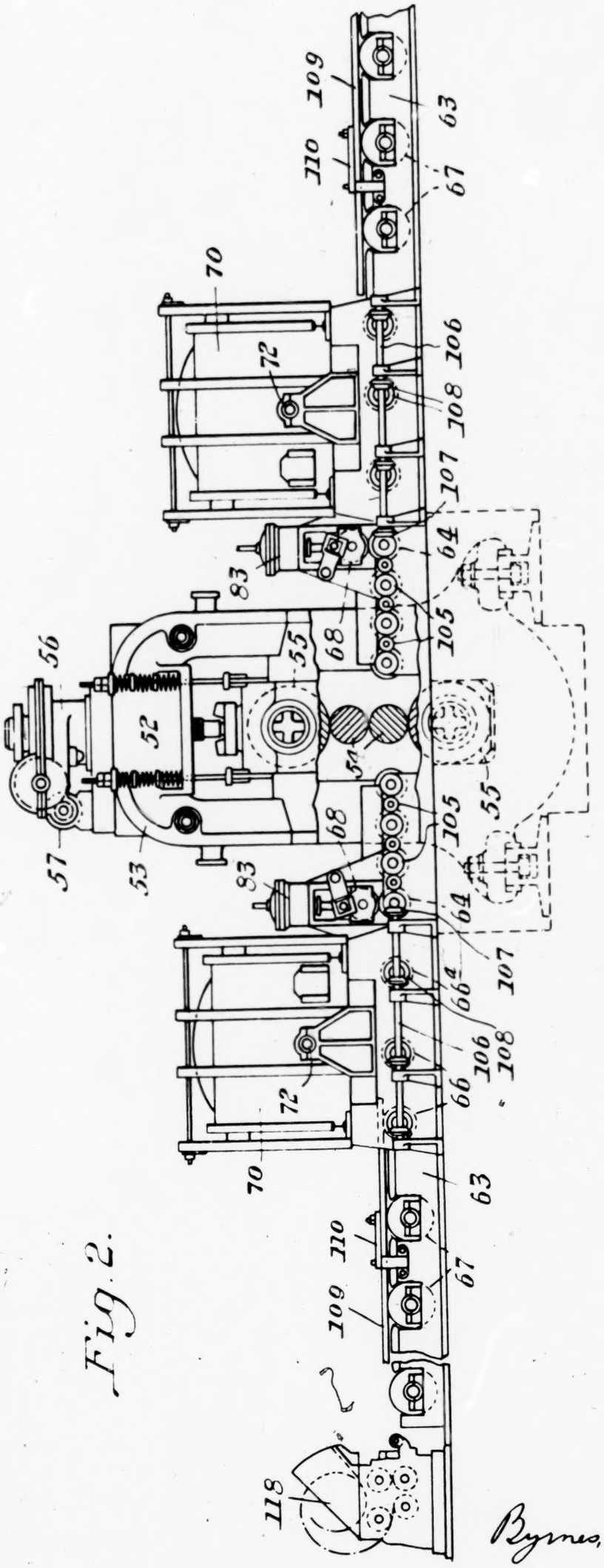


Fig. 2.

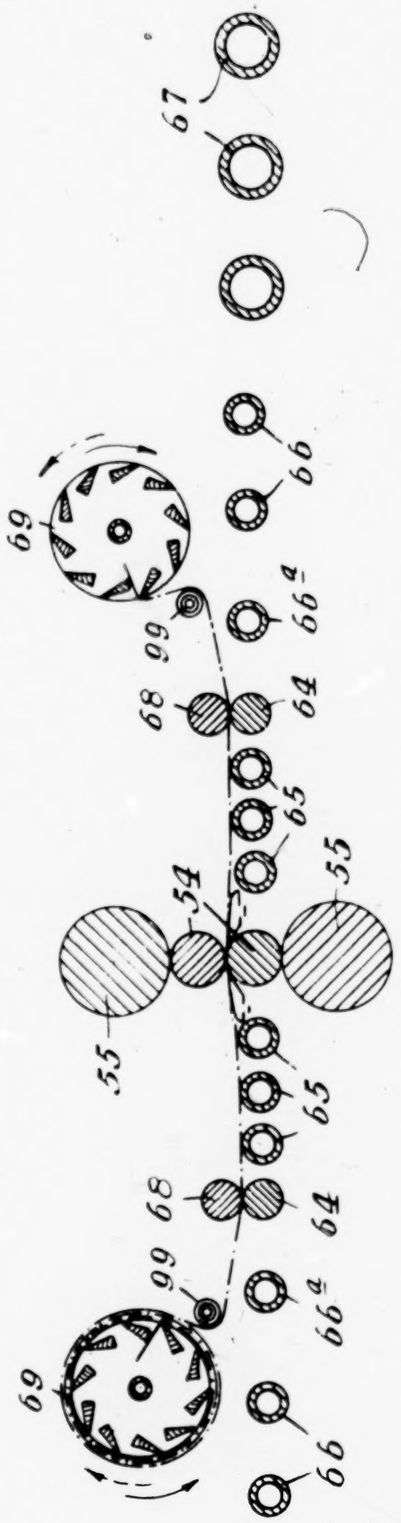


Fig. 3.

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METHOD AND APPARATUS FOR HOT ROLLING STRIP METAL

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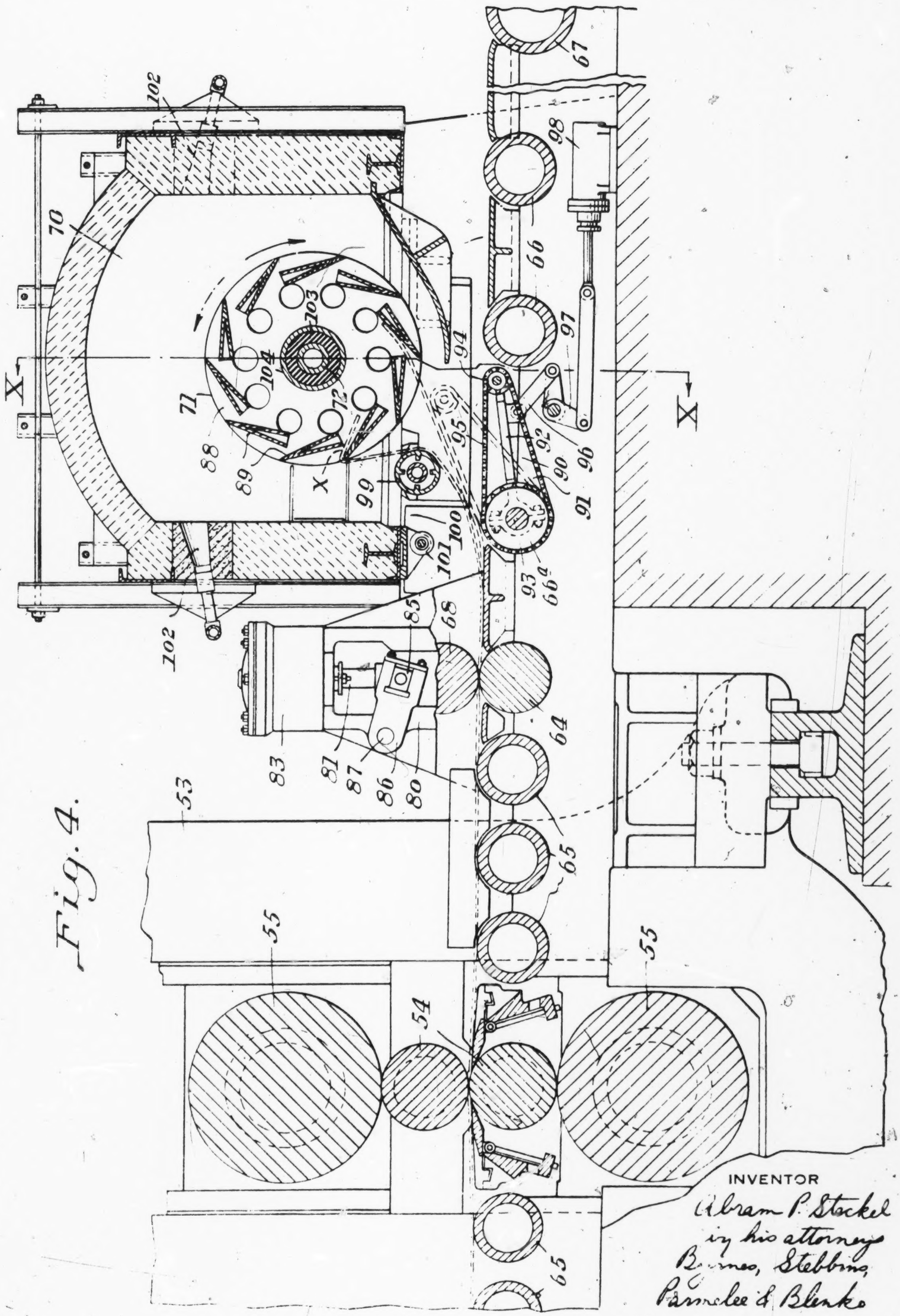


Fig. 4.

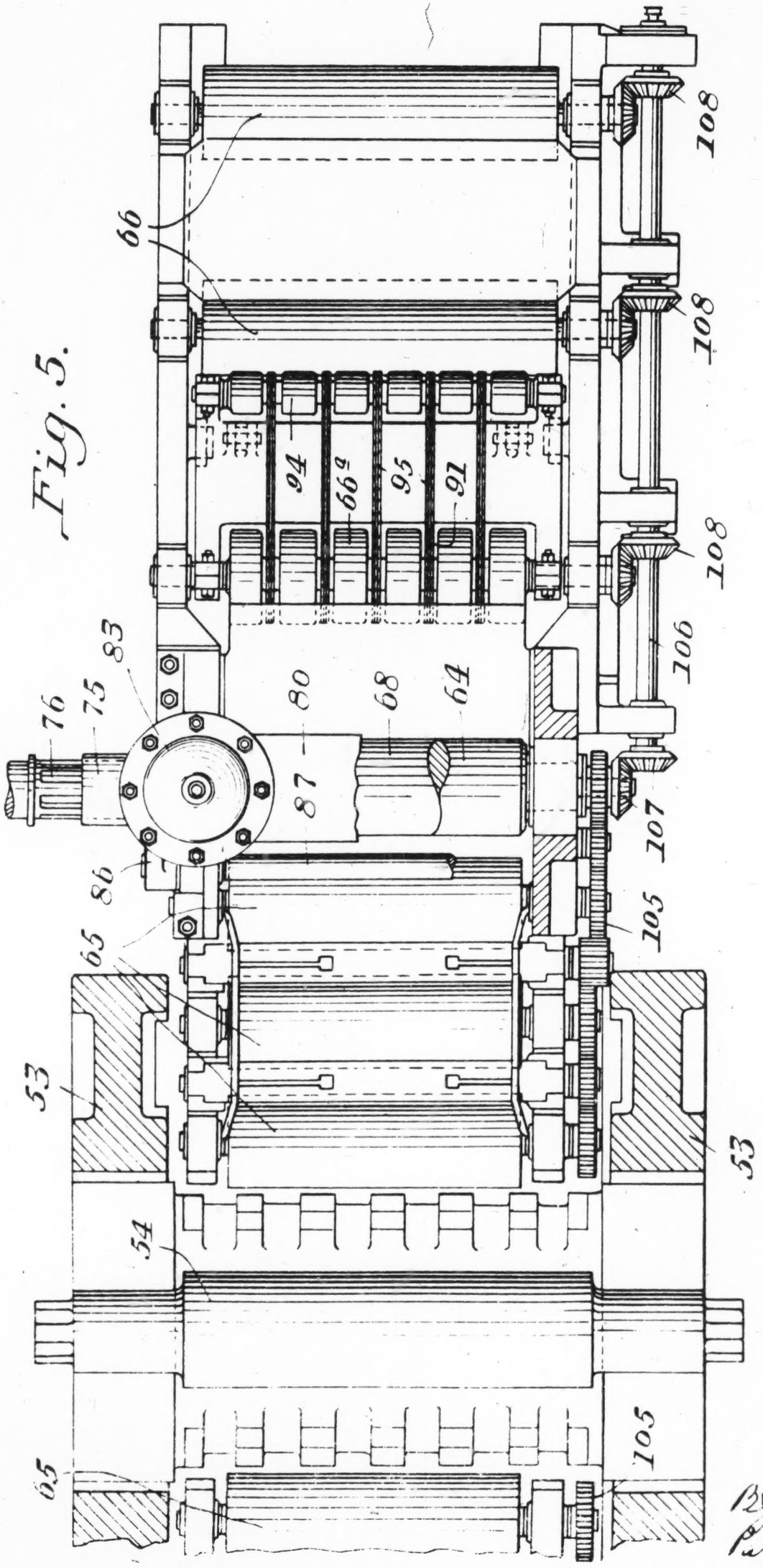
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METHOD AND APPARATUS FOR HOT ROLLING STRIP METAL

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Fig. 5.



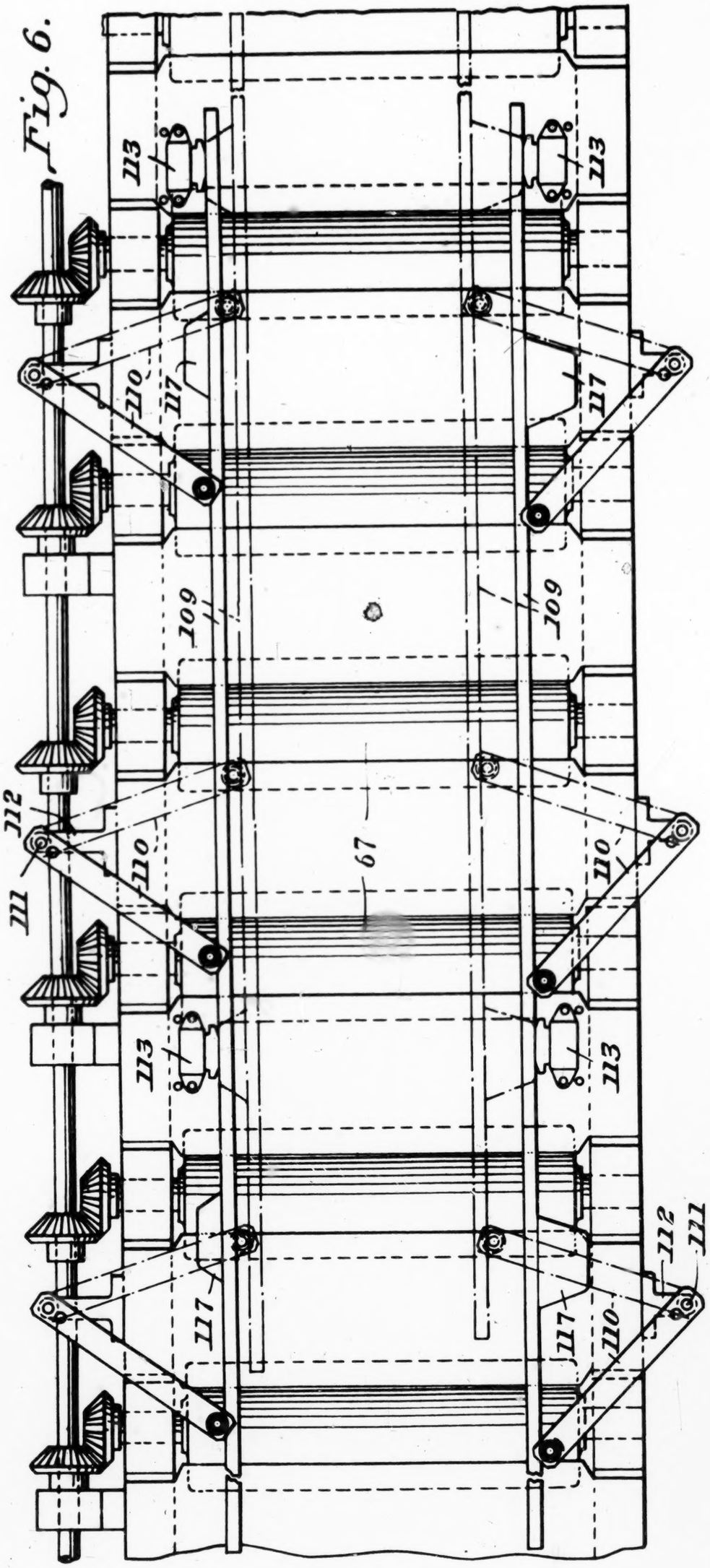
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METHOD AND APPARATUS FOR HOT ROLLING STRIP METAL

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Fig. 6.



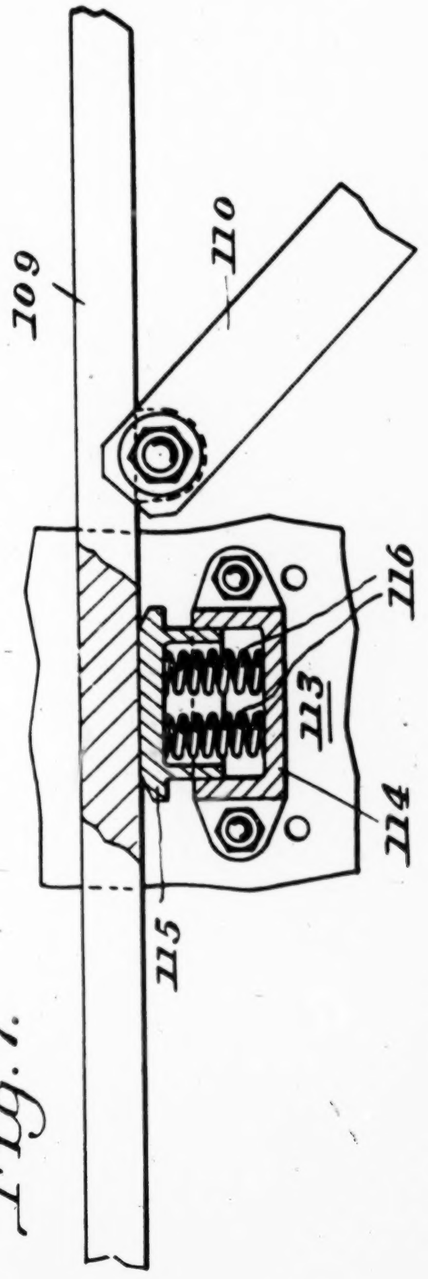


Fig. 7.

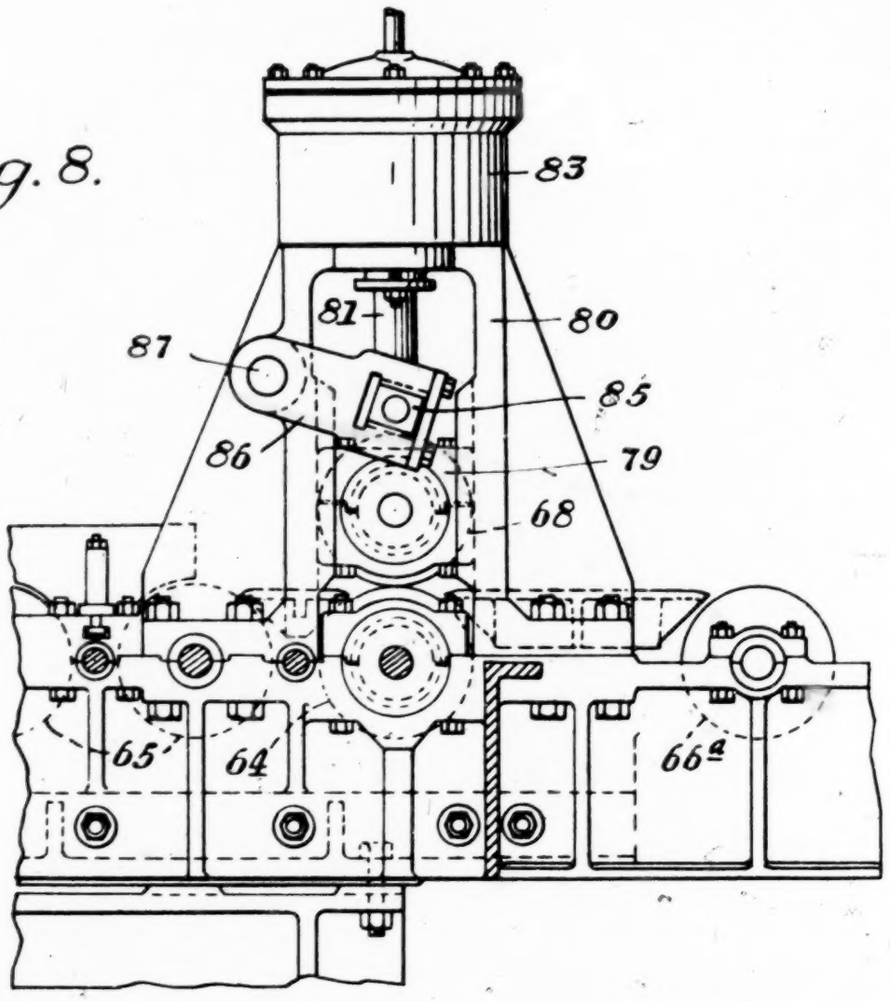
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METHOD AND APPARATUS FOR HOT ROLLING STRIP METAL

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Fig. 8.



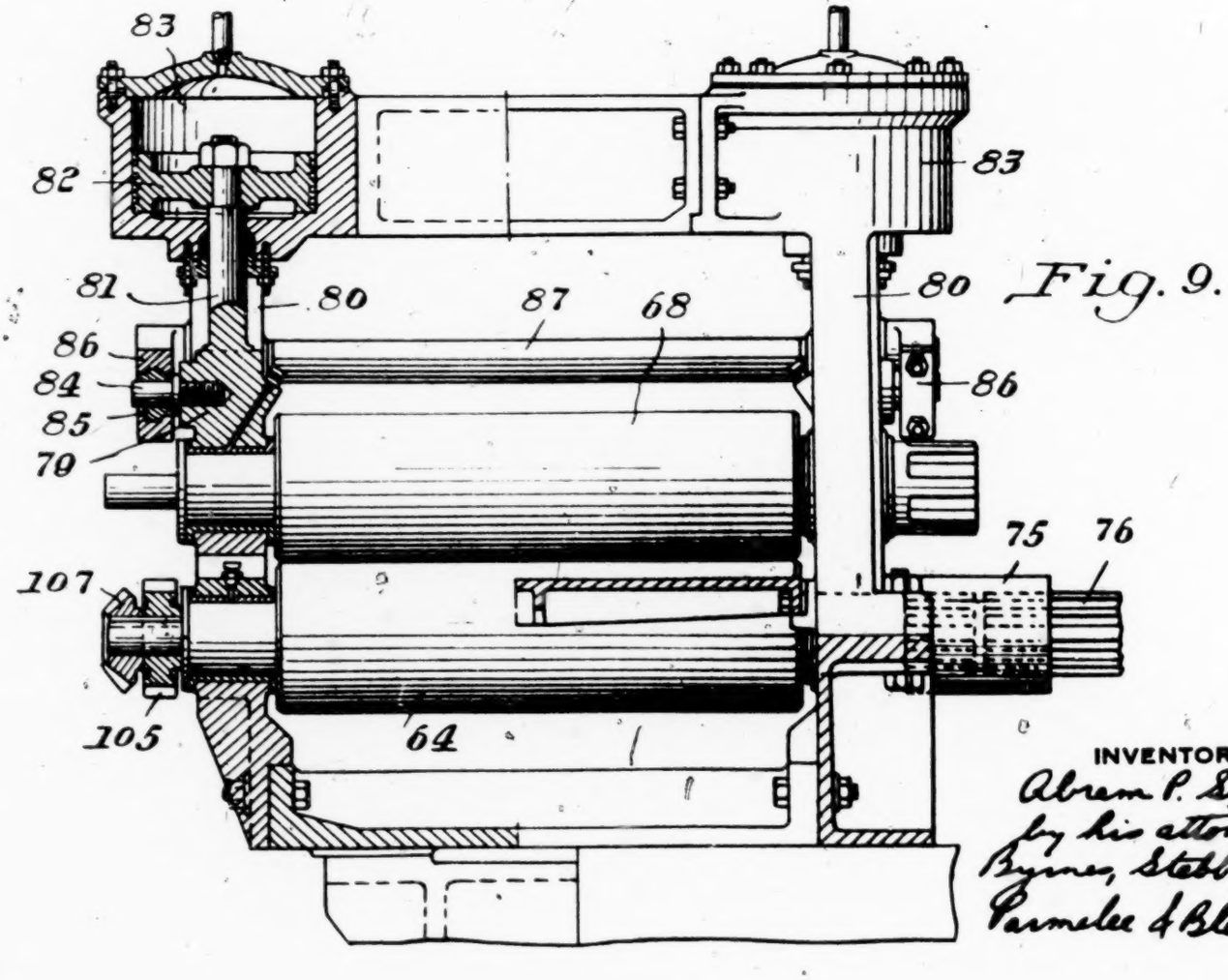


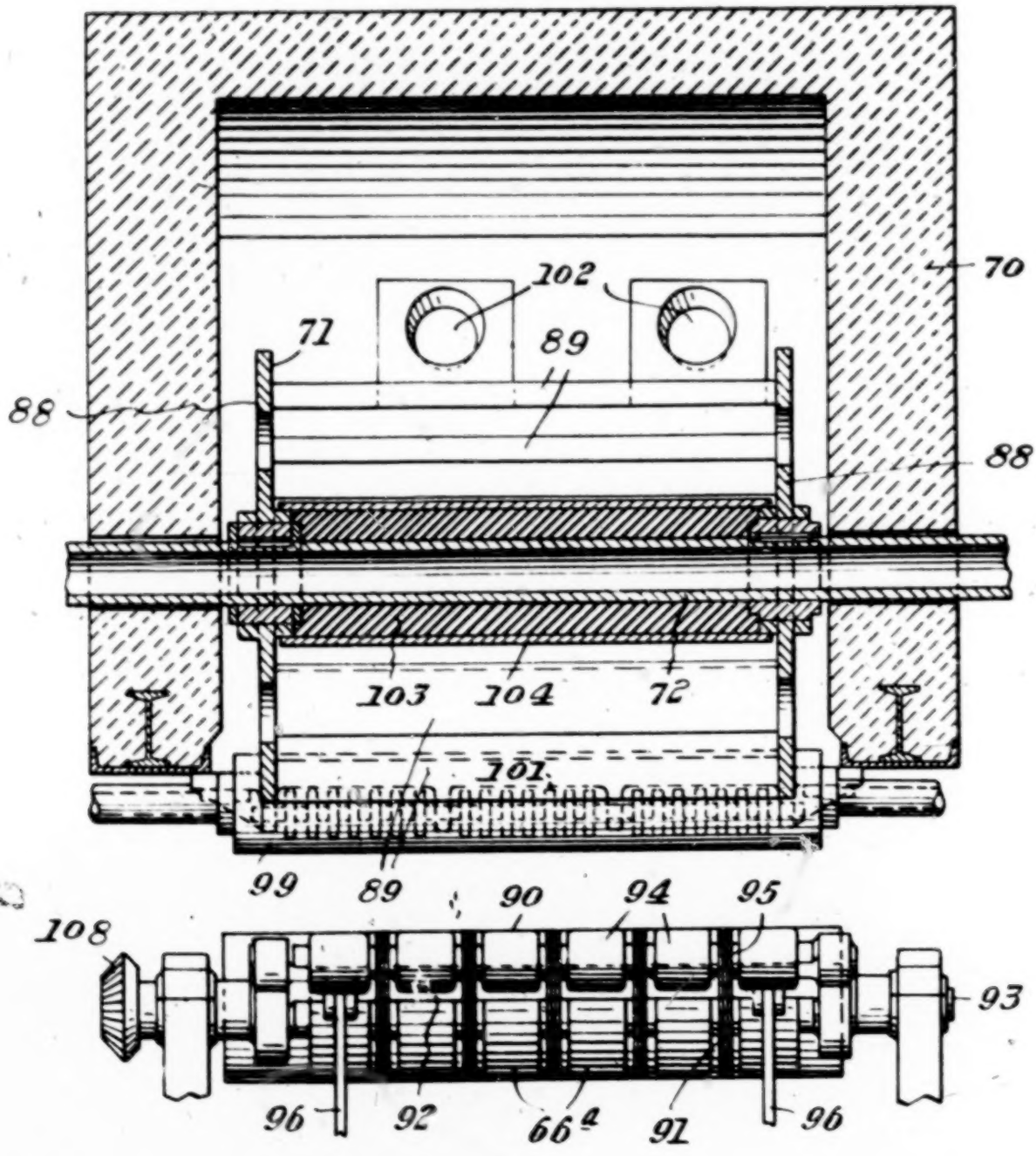
Fig. 9.

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METHOD AND APPARATUS FOR HOT ROLLING STRIP METAL

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Fig. 10.



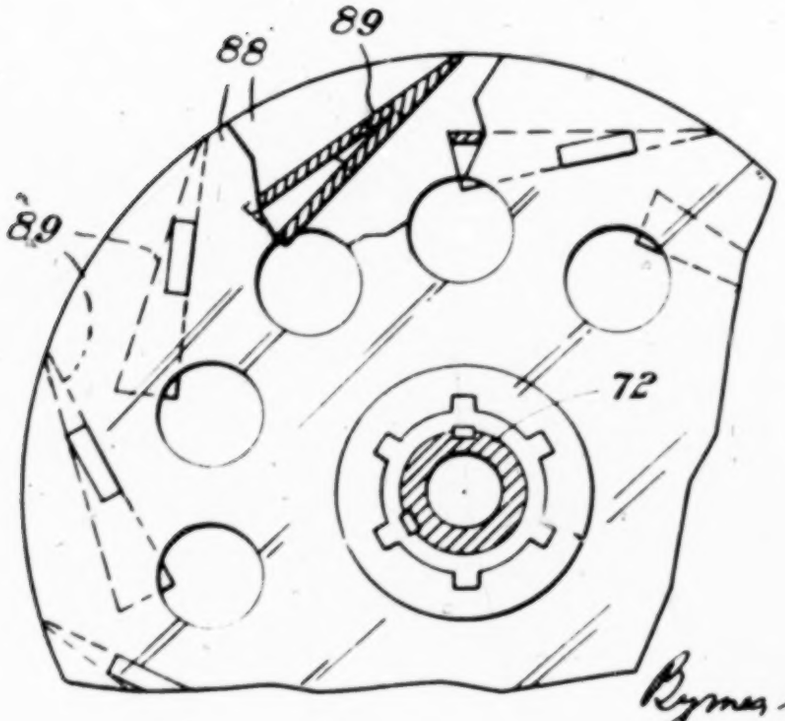


Fig. 11.

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UNITED STATES PATENT OFFICE

1,977,214

METHOD AND APPARATUS FOR HOT ROLLING STRIP METAL

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Application May 4, 1931, Serial No. 535,029

22 Claims. (Cl. 80—2)

This invention relates to the hot rolling of strip metal, the word "strip" being used as a word of general definition, and not of limitation to those classifications of flat metal of indefinite length generally designated for commercial purposes as strip.

The accepted method of rolling strip today is to supply a heated slab to a mill train comprising a large number of stands, say ten, in alinement, the heated slab being elongated and reduced in the successive passes. The early stands operate as tandem mills, that is to say the piece is in engagement with only one stand at a time, but the later stands are generally operated as a continuous mill, that is to say the piece is in process of rolling in several passes at one time. Mills of this character require a very high capital investment and the production is relatively limited. The rate of production is limited by the capacity of the last stand. It is this stand which is operated at the highest speed, the preceding mills being run at successively lower speeds because of the fact that the piece being reduced is relatively shorter. Most of the stands in a continuous mill of this sort therefore are operating at speeds far below the possible maximum, whereas in the type of mill herein disclosed the mill may be operated on each pass at maximum speed or at speeds approaching maximum. As a consequence, it is possible, for a given capacity, to install a mill of my improved type at about one-fourth the cost of a mill of the continuous type.

Such mills also require a very large amount of floor space since all of the rolling is done while the piece is in the flat. Despite the fact that the later stands in the train are operated in a continuous manner, there must still be a reasonable spacing between the mills so as to give access to the stands and to provide for forming a buckle in the piece to accommodate minor discrepancies in the speed of revolution of successive stands which simultaneously engage the piece. There must also be a run-out table beyond the last stand, which run-out table is long enough to accommodate the product. In continuous mills for narrow strip it is common practice to turn the strip on edge and to lap it back and forth over a relatively short cooling bed, but this is not possible with wide strip. The size of such an installation may be appreciated when it is considered that a representative mill of this type having ten stands requires motors whose horse power totals 30,000 and requires a building length in excess of 800 ft. In my improved mill only about one-fifth the motor capacity is required. Yet with this relatively small capacity, approximately half as much tonnage may be produced at one-eighth the total investment.

I provide a mill which is relatively simple and compact in construction, employing preferably but a single reducing stand, although it may in certain instances be desirable to divide the work between two stands. I am able to make each pass at a speed which is determined only by the power supply of the mill and which is not limited by the requirements of a succeeding stand. I prefer to employ a four-high mill of the reversing type, although other types of mills such as a three-high mill wherein the work is fed alternately over and under the middle roll, may be employed.

Each pass will ordinarily be followed by a succeeding pass as rapidly as possible, thereby utilizing practically all of the operating time of the mill.

It is of course well known to reduce the thickness of slabs by rolling them back and forth through a mill stand, but the extent of the reduction has always been relatively limited by two factors, namely, the elongation of the material to a point where it cannot be satisfactorily handled, and the loss of heat to a point where rolling can no longer be profitably continued.

I overcome these difficulties by initially hot rolling a piece of metal in the flat so as to reduce it in thickness sufficiently to permit of coiling it, and in the same heat feeding it from the coil and further reducing it. I preferably employ coilers on each side of the mill and after the initial flat rolling the material is coiled and uncoiled on each pass, the material being fed from a coil to the mill and being coiled up on the other side as it issues.

Mills of the continuous type are designed taking into consideration the rapid loss of heat occasioned by the exposure of the entire surface to the cooling action of the atmosphere. By reason of the fact that as the piece becomes thinner a relatively greater area per unit of volume is exposed for cooling, there is a rapid loss of heat. If, however, this material is coiled, the exposed area is only a very small fraction of the total area of the piece. Furthermore, the coiling permits of using relatively short mill tables, thus saving space and mill cost. The coilers are preferably arranged in heat conserving chambers so as to still further reduce the heat loss and to minimize scaling.

There is a great advantage from the standpoint of heating in initially supplying the hot metal to the mill in slab form. It is practically impossible to uniformly heat a large coil of material to rolling temperature since the edges will always be too hot and the metal of the coil will not be of uniform temperature either from end to end or side to side. With a slab, however, it is relatively easy in existing furnaces to obtain uniformity of heating with a minimum of scale loss.

In order to operate at high speed, it is necessary to have some positive means for feeding the end of the coiled strip back to the mill. For this purpose I prefer to employ pinch rolls on either side of the stand. In practice, the operator will run the mill so as to feed the material in one direction and continue the rolling until the trailing end is out of the grip of the reducing rolls. However, he will bring the mill to a stop before the piece is freed of the pinch rolls. By driving the pinch rolls in a reverse direction, he is enabled to feed the material back to the mill.

The pinch rolls operate to maintain the material under tension and this is highly desirable. It insures straightness of the product and materially simplifies the handling. The pinch rolls on the exit side will be arranged to exert a forward pull on the material, and those on the entering side will be arranged to impart a drag thereto. This causes the material to issue straight. If there are any slight irregularities due to over-rolling at one point or another across the width of the strip, such irregularities will be largely or entirely removed.

During the early stages of the rolling mill when the material is in slab form it is sufficiently stiff even at rolling temperature that it may be thrust forward by the rolls or by the pinch rolls very rapidly. When it is quite thin there is a tendency of the material to buckle as it issues from the mill or from the pinch rolls unless it is taken up by the reel as fast as it issues. The reel must be of such construction as to engage the material positively and without delay. I employ a form of reel which serves this purpose and which also is effective in combination with other apparatus employed for breaking or loosening the scale between passes, thus insuring that no scale will be rolled into the surface of the strip, reducing its quality. This form of reeling mechanism, however, operates most satisfactorily only after the material is relatively thin. There is an intermediate stage of reduction between the flat rolling of the thick slab and the reeling of the thin material which, for purposes of heat saving, and economy of installation by reason of shortening of the tables, is best carried out by reeling the material. I employ the same reels for this material of intermediate thickness but operate them in the opposite direction, as hereinafter explained.

There are certain difficulties attendant upon rolling the material in the flat at the high speeds I contemplate, which difficulties must be overcome to make the installation desirable. As the material is reduced in thickness, it widens. In the early stages of rolling, where the slab is still relatively short, it is not so important that it be fed exactly squarely into the rolls, but as it increases in length its alinement becomes more and more important. In order to obtain such alinement, side guides must be employed, which side guides necessarily are spaced for entering the piece a distance only slightly more than the width of the piece being entered. On the exit side of the mill, however, the guides should have a relatively wider spacing in order to prevent cobbling. I provide automatically operable guides which fulfill these requirements.

In the accompanying drawings, illustrating a present preferred embodiment of my invention,

Figure 1 is a top plan view of the mill;

Figure 2 is a side elevation to an enlarged scale of a portion thereof;

Figure 3 is a diagrammatic view illustrating the operation of the mill;

Figure 4 is a vertical longitudinal section through the mill stand and one of the coilers;

Figure 5 is a top plan view, partly broken away, of that portion of the installation illustrated in Figure 4;

Figure 6 is a top plan view of a portion of one of the tables showing the guides;

Figure 7 is a detail view, partly broken away, showing a stop for the guides;

Figure 8 is a side elevation of the pinch roll structure;

Figure 9 is an elevation at right angles to the elevation of Figure 8, and partly broken away;

Figure 10 is a transverse section taken on the line X—X of Figure 4, certain parts being omitted for sake of clearness; and

Figure 11 is a side elevation, partly broken away, of one of the coiling reels.

Referring first to Figures 1 to 3 inclusive, there is shown a mill stand indicated generally by the reference character 52 and comprising housings 53 supporting work rolls 54 and backing rolls 55. The backing rolls are preferably provided with anti-friction bearings as described and claimed in my U. S. Patent No. 1,779,195. The mill is provided with screw downs indicated generally by the reference character 56, which screw downs are actuated by an electric motor 57 controlled from the operator's pulpit 58 so that the setting of the mill may be rapidly adjusted. The work rolls 54 are driven by a motor 59 through reducing gears 60, pinions 61 and spindles 62.

A mill table indicated generally by the reference character 63 is provided at each side of the stand 52. A roll 64 spaced a short distance from the work rolls is provided on each side of the mill. Relatively closely spaced table rollers 65 lie between the stand and the rolls 64, and more widely spaced rollers 66 and 67 lie therebeyond. The rolls 64 cooperate with rolls 68 to form a pinch roll unit effective for engaging material. The rolls 68 are arranged to be raised or lowered as desired. At the beginning of a rolling a hot slab is supplied to one of the tables 63 and is fed to the mill which reduces and elongates it, delivering it to the roll table 63 on the opposite side. The mill is then reversed and the operation is repeated. This continues until the slab is thinned sufficiently to permit of coiling it. When this stage of reduction is reached, the material is deflected upwardly from the plane of the tables 63 to coilers. The coilers are indicated generally at 69 in the drawings and are contained in heated chambers 70 lying above the tables 63. The coilers comprise reels 71 mounted on shafts 72 driven by motors 73 through gears 74.

The pinch roll structure is best illustrated in Figures 4, 8 and 9. The rolls 64 are driven through coupling boxes 75 and spindles 76 from motors 77 (see Fig. 1) through reducing gears 78. The motors 77 are controlled from the operator's pulpit 58 as are the motors 73 and 59.

The rolls 68 are mounted in bearings 79 slidable

in housings 80. A piston rod 81 extends upwardly from each bearing 79 to a piston 82 in a cylinder 83 formed in the upper part of the housing 80. The pistons 82 may be raised or lowered by controlling the supply of air to the cylinders 83. The movement of the cylinders is also controlled from the operator's pulpit 58. In order to insure simultaneous raising and lowering of the bearing 79 for each end of a roll 68, the bearings are interconnected. Each bearing carries a stud 84 extending through a block 85 slidable in the forked end of a lever 86. The levers 86 are keyed to a rocked shaft 87 so that the bearings 79 are bound to move up or down together.

The coiling mechanism is best illustrated in Figures 4, 5, 10 and 11. Each reel 71 comprises spaced disks 88 with V-shaped bars 89 extending therebetween to form a squirrel cage. The reels may be driven in either direction as desired.

A kick-up indicated generally by the reference character 90 is provided in each table 63 for deflecting material upwardly to the coiler. Each kick-up comprises a driven table roller 66*a* having circumferential grooves with sprocket teeth 91 therein. A frame 92 is pivoted on the shaft 93 of the roller 66*a* and carries a roller 94 having toothed circumferential grooves corresponding to those of the roller 66*a*. Sprocket chains 95 extend around these teeth, the upper flight of the chains lying in the plane of the table when the frame 92 is in its lowered position. The frame 92 is connected by a link 96 to a bell crank 97 which is actuated by a fluid cylinder 98. The cylinder is controlled from the operator's pulpit 58.

When it is desired to coil a strip of material fluid pressure is supplied to the cylinder 98, causing the bell crank 97 to be rotated in a counterclockwise direction, as viewed in Figure 4, and tilting the frame 92 upwardly about the shaft 93. This moves the kick-up to the dot and dash line position of Figure 4 and guides the leading end of the oncoming material into the chamber 70. It is preferred that the reeling be commenced when the material is relatively thick, say ¾ of an inch. For handling material of such thickness the reel 69 is driven in the direction indicated in Figure 4 by the arrow shown in dotted lines. The leading end of the relatively thick and stiff strip passes between adjacent bars of the squirrel cage 71. The peripheral speed of the reel approximates the entering speed of the material and the reel gathers such material as it is fed forward by the pinch rolls. After the reeling in one direction is completed, the direction of rotation of the pinch rolls, the mill and the reel is reversed and the piece is fed back for another pass.

After the material gets sufficiently thin (say about ½ inch) that it becomes practical to bend it sharply, it is desirable to impart such sharp bending so as to loosen the scale and permit it to fall off. Therefore, when the material reaches this thinness, the receiving reel is driven in the direction indicated by the solid arrow. The entering end of the steel being rolled passes between adjacent bars of the squirrel cage 71 and the rotation of the squirrel cage causes the strip to be doubled over the edge of one of the bars 89, as indicated at X in Figure 4. The material thereafter travels around a scale breaking roll 99.

When the material reaches this thinness the question of scale formation becomes important. If scale is not removed between passes it is rolled into the strip and also injures the face of the work rolls in the mill. The formation of a small amount of scale after the rolling has been completed is relatively unimportant, but the continued passing of scaly material through the rolls must be overcome. The flexing of the material around the roll 99 breaks the scale and it is dropped or thrown off prior to the next rolling, thus giving a cleaner product and insuring long life for the work rolls. I term the first mentioned type of coiling "tangential coiling" and the other type as "reverse coiling".

It is intended that the operator will stop the movement of the material just after its trailing end leaves the work rolls 54 and before it passes out from the grip of the pinch rolls 64 and 68, but in the event that he does not check the movement in time and the entire strip is wound on the coiler, the outer end may be readily engaged through a space 100 and fed back to the pinch rolls by tongs. A guide roll 101 protects the surface of the material during such procedure.

The chambers 70 are made of refractory material and will be kept up to a desired temperature in operation by means of fuel burners 102. Relatively only a small amount of heat will be required as the material may be rolled so rapidly in the mill and with such frequency that enough rolling energy is transformed into heat to very materially retard cooling. This is particularly so because of the fact that only a relatively small portion of the length is exposed to atmospheric cooling from the time it issues from the rolls until it is in the coiler.

The shaft 72 of the reel is provided with insulation 103 and a protecting sleeve 104. The shaft 72 being hollow, it is readily maintained at sufficiently low temperature to insure adequate strength. Air cooling alone may be sufficient, but I prefer to let a small quantity of water trickle through. Because of the insulation 103 there is no danger of loss of heat or of chilling the interior wraps of the coil of metal.

It is found in practice that the doubling back of the material over the bars 89 to obtain initial engagement of the reel with the strip is not detrimental to the quality of the material as the bend is not through an unduly large angle, and the metal thereat is kept at elevated temperature and the bend rolled out in the mill.

The construction of the roll tables 63 and the side guides is best shown in Figures 1, 2 and 5 to 7 inclusive. The table rollers adjacent the mill are driven by the motor 73. The roll 64 forming the bottom pinch roll is connected through a spur gear train 105 to the rollers 65. The roll 64 also drives a shaft 106 through miter gears 107. This shaft extends along the table 63 and, through miter gears 108, drives the table rollers 66 and 66*a*. The rollers 67 are driven in a like fashion and may be operated from a separate motor. This will usually be desirable because such rollers will be idle during the entire portion of the operation when the metal is being coiled between passes.

The side guides comprise metal bars 109 connected to parallel links 110 pivoted at 111 on brackets 112 secured to the sides of the table. The bars 109 rest on the table rollers 67. The table shown in detail in Figure 6 lies at the left hand side of the mill as viewed in Figures 1 and 2, and the solid line position of the guides is their open position which is desired when receiving material. Assume now that a slab of metal to be rolled is lying on such table and it is desired to feed the same to the mill. The rolls 67 are rotated in such direction as to carry the metal to the right. By reason of the frictional engagement of the side guides 109 with the rollers, such

guides are also carried to the right, swinging on the links 110. By reason of such movement they assume the position shown by dot and dash lines, and it will be noted that the guides in this position are much closer together and are effective for accurately alining the entering material. The further movement of the guides is limited by stops 113, which stops consist of casings 114 bolted to the mill table and carrying buffers 115 backed by coil springs 116.

When the rollers 67 are driven in the reverse direction the side guides are urged to the left as viewed in Figure 6 and swing back to the solid line position, their movement in this direction being limited by the side guides proper coming into engagement with the stops 113. The side guides are provided with pads 117 which engage the stops when the guides are at their inner position. The links 110 are provided with an extra hole or holes at their outer end through which they may be pivoted at 111 so as to vary their effective length and hence the spacing of the guides. The table is provided with a corresponding series of holes as shown in Figure 7, so that the stops 113 may be adjusted to correspond.

It will be noted that the initial angularity of the links on one side of the table differs from the initial angularity of the links on the other side of the table. The reason for this is that as the links move from the solid line to the dot and dash line position they move inwardly so long as the links are traveling toward a position of perpendicularity with respect to the axis of the table, and then slightly outwardly as the links move from such perpendicular position to their position of rest. If the initial angularity of the links on the two sides of the table were the same, such links might reach a condition of perpendicularity at the same moment, thus possibly bringing the guides so closely together as to interfere with the travel of the piece. However, this does not occur with the construction shown. On the contrary, the side guide shown at the upper portion of Figure 6 reaches its innermost position somewhat ahead of the guide on the opposite side. In so doing it engages the edge of the material and alines it. Then in coming to its position of rest it moves away from the material a slight distance so as to give it utter freedom of movement toward the mill, while limiting its sidewise movement to the slight clearance afforded by the travel of the links beyond their position of perpendicularity. The side guide shown at the lower portion of Figure 6 also engages the edge of the strip if the same is mis-alined, and thereby straightens it up for its travel into the mill.

In operation a heated slab of material will be supplied to one of the tables 63 and run back and forth through the mill, the screw down being operated so as to bring the rolls successively closer together, thus thinning and elongating the piece. These passes will be very rapid and with the least possible loss of time, thus getting the strip down to a thinness suitable for coiling without serious loss of heat. When the material is thin enough to coil, the kick-ups will be actuated to feed the issuing strip to one of the coilers. The rolling will then be continued, feeding from one coil to another, the pinch rolls serving to feed the material. After the rolling has been completed the material will be permitted after the last pass to travel to the end of the left hand table 63 and to a centerless coiler 118 of usual construction, from which it may be taken away.

I have illustrated and described a present preferred embodiment of the invention. It will be understood, however, that this is by way of illustration only, and that it may be otherwise embodied or practiced within the scope of the following claims.

I claim:

1. In combination with a rolling mill adapted for the rolling of material first in one direction and then in the other, a roll table, a coiler above the table, and means for diverting material from the roll table upwardly into the coiler, the coiler having a portion rotated in such direction that when it engages the leading end of the material being rolled it has a component of motion in a direction opposite to the movement of such leading end, and a guide roll associated with the coiler around which the material passes, the guide roll being spaced above the table a distance sufficient to permit of travel of the material over the table when such material is being rolled and maintained in the flat condition.

2. In combination with a mill, a mill table on either side of the mill arranged to support material while the same is rolled back and forth through the mill, means for effecting coiling of the material on either side of the mill as it issues therefrom, and pinch rolls for engaging the issuing material prior to the coiling thereof, the pinch rolls being in the plane of the table but so arranged as to be out of the way of material rolled back and forth on the mill tables.

3. In combination with a mill, pinch rolls on either side of the mill for tensioning issuing material, means beyond the pinch rolls for effecting coiling of the material, and means for retaining the heat of the coiled material.

4. In combination with a mill, a table on either side of the mill of such character as to support a flat piece of material from the time of issuance thereof from between the rolls of the mill until it has been fed back through the mill, the tables being effective for supporting the material while it is relatively thick and in an uncoiled state, and coilers adapted for automatically reeling and paying out material rolled on the mill when the same has been thinned and elongated, sections of the table being movable to divert material from the tables to the coilers.

5. In combination with a rolling mill, a mill table on either side of the mill arranged to support material while the same is rolled back and forth through the mill in the flat state, means comprising sections of the table for deflecting material upwardly from the plane of the tables, a coiler on either side of the mill for engaging and coiling the deflected material, and chambers above the plane of the tables containing the coilers, the chambers being arranged to prevent loss of heat of the coiled material.

6. In combination with a rolling mill, a table having rollers rotatable in either direction, a side guide movable on the rollers, and means for moving the side guide inwardly when the rollers rotate to move the guide in one direction and outwardly when they rotate to move it in the other direction.

7. In combination with a rolling mill, a table having means for moving material therealong, and a side guide resting on the material moving means and movable therewith, means engaging the side guide arranged to move it laterally on actuation of the material moving means.

8. In combination with a rolling mill, a table having means for moving material therealong, and a side guide movable laterally of the table

when the material moving means is actuated, there being a frictional driving connection between the material moving means and the guide.

9. In combination with a rolling mill, a table having material moving means, a side guide resting on the material moving means, laterally extending links connected to the side guides, and stop means for limiting movement of the side guides.

10. In combination with a rolling mill, a table having material moving means, side guides resting thereon, there being a side guide adjacent each side of the table, the side guides being movable with the material moving means, links connected to the side guides, and stop means for limiting the movement of the guides, the links for one side guide being at a different inclination than the links for the other side guide when the guides are at the end of their travel.

11. In the method of hot rolling, the steps consisting in subjecting hot material to successive reducing passes to thin and elongate it, coiling it between passes and flexing it between passes, and prior to coiling, sufficiently to effect removal of formed scale.

12. In the method of rolling, the steps consisting in hot rolling a flat piece of metal to reduce it sufficiently in thickness to permit of coiling it, thereafter subjecting it to repeated reducing passes, coiling it between passes, and removing scale from the material between passes.

13. In combination with a rolling mill, a coiler on each side of the mill for effecting coiling of the material, and means for flexing material between passes in the mill, and prior to coiling, sufficiently to effect removal of scale therefrom.

14. In the method of rolling, the steps consisting in subjecting material to successive reducing passes, feeding it to a coiler between passes, coiling it in one direction between certain of said passes, and coiling it in the other direction between other of said passes.

15. In the method of rolling, the steps consisting in subjecting material to successive reducing passes, coiling the material tangentially between passes, and, at a later stage in the operation, coiling it in the reverse direction between passes.

16. In the method of rolling, the steps consisting in subjecting material to successive reducing passes, coiling the material tangentially between passes, and, at a later stage in the operation, coiling it in the reverse direction between passes, and flexing the material through a relatively sharp bend during such reverse coiling so as to effect removal of scale.

17. In combination with a rolling mill adapted for the rolling of material first in one direction and then in the other, a roll table for feeding material to the mill, a pinch roll cooperating with a roll of the roll table, means for driving one of the cooperating pinch rolls, a second pinch roll cooperating with a roll of the table on the opposite side of the mill from the first-mentioned pinch roll, and means whereby said second-mentioned pinch roll exerts a restraining tension on said material.

18. In combination with a rolling mill adapted for the rolling of material first in one direction and then in the other, roll tables on each side of the mill and coilers above the roll tables, sections of the tables being movable upwardly to divert material to the coilers.

19. In combination with a rolling mill and a table therefor, a side guide positioned over the table and movable longitudinally thereof, and connections for the side guide effective for moving it laterally of the table upon longitudinal movement thereof.

20. In combination with a rolling mill and a table therefor, a side guide positioned over the table and movable longitudinally thereof, connections for the side guide effective for moving it laterally of the table upon longitudinal movement thereof, and stops for limiting such lateral movement, the stops being so positioned that the guide occupies one position laterally of the table upon longitudinal movement in one direction, and another position laterally of the table upon longitudinal movement in the other direction.

21. In combination with a rolling mill and a table therefor adapted to feed material to the mill or to receive the same therefrom, side guides lying over the table and movable longitudinally thereof, connections for the side guides effective for causing lateral movement thereof when the side guides are moved longitudinally of the table, and stops for limiting such lateral movement, the stops being so positioned as to leave the side guides relatively closely spaced for a feeding action and relatively more widely spaced for receiving material from the mill.

22. In combination with a mill for rolling material in either direction, roll tables on each side of the mill, reels arranged above the roll tables for coiling material issuing from the mill and for feeding coiled material back to the mill, heat conserving chambers surrounding the reels, the chambers lying above the roll tables and being open at the bottom, and kick-ups for diverting material from the roll tables through the bottoms of the chambers to the reels.

ABRAM P. STRCKEL.

Demonstrates New Principle Of Rolling Hot Strip

APPLICATION of the Steckel-type mill to the hot rolling of strip was demonstrated last week by officials of the Cold Metal Process Co. to a group of about 60 engineers including 14 from France, Belgium, Germany, England, Wales, Sweden, Czecho-Slovakia, Italy and the Saar. The mill, an experimental assembly, is located at the Brier Hill plate mill division of the Youngstown Sheet & Tube Co., Youngstown, O.

Only one stand of 4-high rolls is used, this being served by two elevated holding furnaces, one spanning the approach table and the other the runout table, as shown in the accompanying illustration. Mounted inside each furnace is a 48-inch diameter reel made of chrome-nickel heat-resisting steel. The purpose of the furnaces is merely to restore the initial heat of the slab so that as the partially-rolled piece emerges from the furnace and enters the rolls, the temperature will be uniform throughout its length.

During the demonstration slabs 4 inches thick, 9 feet long and weighing approximately 2500 pounds were used as the raw material. Each slab, heated to about 1600 degrees Fahr., is brought from the slab heating furnace by crane, deposited on the approach table leading to the mill, and then run through a scale breaker. While in transit through this unit the steel passes between two circular steel brushes which rotate at high speed and loosen the scale on both the top and bottom surfaces and, as the piece progresses, sprays of high-pressure water, directed against both surfaces, remove the loosened scale.

After the slab leaves the scale breaker it enters a set of pinch rolls, equipped with an air-operated hold-down and driven by a separate motor, which direct it into the 4-high mill equipped with 20-inch diameter work rolls and 36-inch backup rolls, all with 72-inch body. The steel is given 11 passes back and forth through the mill and, following each reduction, is conveyed beneath the holding furnace spanning the roller table, away from the mill.

Previous to the eleventh pass a set of dogs is canted on the roller table on the runout side and, as the front end of the piece emerges from the mill and finally the pinch rolls, it is directed at an upward angle by the dogs into the holding furnace and reeled into a coil while reduction of the remaining section continues. The holding furnace is gas fired and preserves the steel at 1600 degrees Fahr., the initial temperature of the slab.

Pinch Rolls Are Automatic

When the rear end of the piece emerges from the mill and is still in the grip of the pinch rolls at the exit side, the mill is reversed and the strip returns through the work rolls and pinch rolls and into the opposite holding furnace where it again is reeled and restored to a temperature of 1600 degrees. To prevent excessive tension on the piece in the process of reduction, only one set of pinch rolls functions, this always being on the rear side of the mill for the purpose of pulling the stock through the rolls and off the reel at the entrance side.

Reduction continues with the piece being coiled and uncoiled from the eleventh pass to the end of the fifteenth pass. Following the sixteenth and final pass when 4-inch slabs are on schedule, the steel instead of entering the holding furnace is conveyed away from the mill by a roller table to a cold, motor-driven reel and wound into a coil. As delivered to this coiler, the piece measures 400 feet long and 20 inches wide and gages 0.109-inch or about 12 gage.

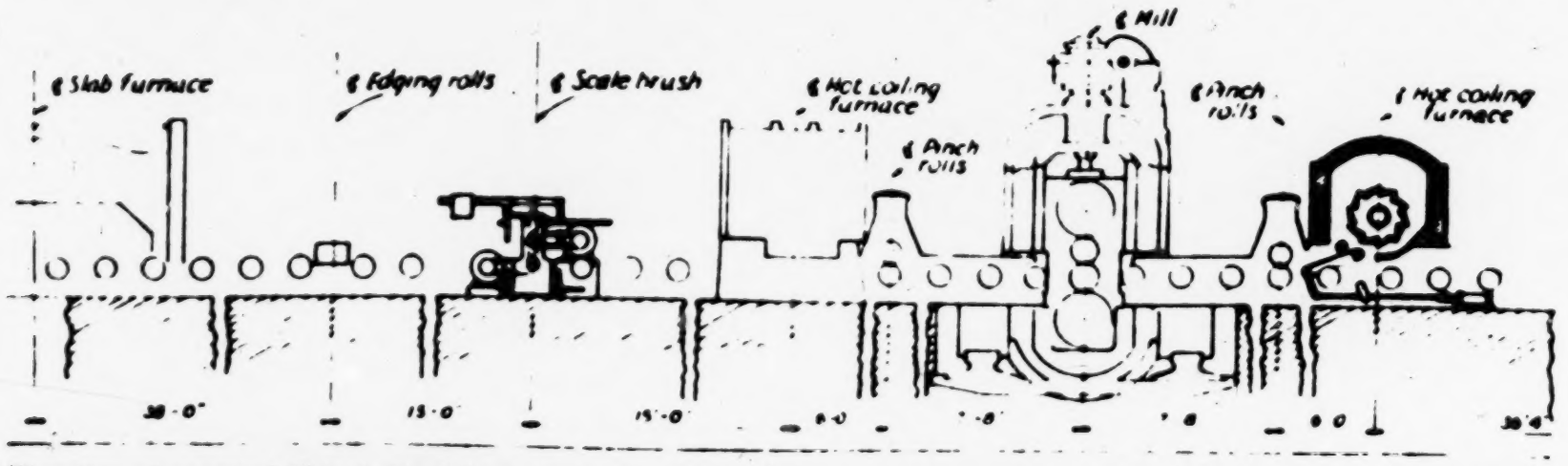
The present mill is only an experimental assembly of apparatus and is not indicative of the full capabilities of this new type construction. The maximum rolling speed possible in the present setup is only 300 feet a minute and will be increased to about three times this speed in the next installation.

Based on the present low speed, a slab 4 inches thick and 9 feet long is converted to strip of about 12 gage (0.109-inch) in 6 to 6½ minutes. A conservative estimate of the effect of three times faster speed would be to reduce this rolling cycle to less than 3½ minutes.

Lighter Construction Suitable

The massive housings and air-cylinder construction over the pinch rolls will not be repeated in any future mill since experimental operation has proven that pinch rolls are necessary merely for manipulating the ends of the piece. This will require only a light weight device instead of the present cumbersome construction, which was provided because of the original intention to exert a heavy pull on the material through the pinch rolls. While motors of 150 horsepower are used on the experimental mill to drive each pair of pinch rolls, only 50-horsepower drives will be employed on future installations.

The product rolled at present has considerably more crown than will be tolerated but the development of this refinement has been postponed purposely to save the expense involved in regrinding and changing rolls. While no edging rolls are used on the experimental setup they will be included in the design of any future mill in order to hold any desired width of product and to break up the initial furnace scale.



Elevation of proposed 48-inch Steckel-type hot mill which employs a single stand of 4-high rolls for converting slabs to strip and holding furnaces for maintaining uniform temperature during reduction

scrap was used in the fabrication, thereby further reducing the costs. It is estimated that the average saving on welded construction was 45 per cent.

All welding was done in the Republic shops using one 600 ampere, two 400 ampere and two 300 ampere machines all manufactured by the Company with which the writer is connected. The shielded arc process of welding using heavily coated electrodes was utilized exclusively. The sizes of electrodes used were 3/16", 5/16" and 1/4".

Hot Rolling—Cold Rolling—Single Stand Mills—Continuous Mills

By A. P. STECKEL
President, Cold Metal Process Company, Youngstown, Ohio.

Presented before the Cleveland District Section of the A. I. & S. E. E., December, 1922.

Your large assembly here this evening results, no doubt, from the interest your membership takes in subjects which have to do with the advancement of all forms of engineering to your industry. I intend to discuss the merits of working with single stand mills, as compared with continuous mills, both in the fields of hot rolling and of cold rolling.

Development of four-high roller bearing mills in the past few years and extensive use of them in sizes from the largest to the smallest, clearly indicates, for the immediate future, a very broad general application of the strip process to the production of all flat products, beginning with plates, and ending only with the very thinnest materials. Such new development means, of course, the abandonment of two-high and three-high hot mills in rolling the wide flat products and also, largely, the abandonment of two-high cold mills, not only in the wider sizes but even down to the very narrowest mills. These developments, in fact, mean nothing but a cure for the weaknesses that were always inherent in two-high mills when employed on wide flat products in hot rolling, and the much more pronounced weaknesses of the two-high mill when employed in cold rolling of all widths.

Up to a few years ago practically all rolling of all sorts, whether hot or cold, was done on two-high mills. For this reason we should not speak too confidently of their abandonment without giving convincing proof of their limitations as well as proof that the mills that are to supplant them have surmounted these limitations. The satisfactory ability of two-high mills to roll rounds, squares, rails, structural sections, and relatively narrow widths of hot strip even in long lengths is well proven, and will doubtless stand, but the two-high mill runs into most serious limitations on wide sections, especially if width occurs in connection with thinness of product. That is, of course, because roll pressures increase directly with the width of product rolled, and also with the hardness of the product. The much greater hardness encountered in cold rolling naturally ran the rolling pressures up tremendously and consequently left no practical means for cold rolling hard metals such as steel except recourse to very low speed.

Fifty years or more ago the inherent weakness of two-high mills as to bending of rolls when rolling wide plates was recognized and cured by a Mr. Lauth who stiffened the mill against roll bending by developing the three-high design. The still better four-high design is perhaps as old as the three-high, but we want to emphasize that both of these old developments aimed only at stiffening the mill against roll deflection, which in fact they did accomplish.

However, in neither the old three-high nor old four-high design was there any aim to raise the possible rolling speed of the mills by doing anything to improve the capabilities of the bearings that carried the rolling load. It should be noted here that both the old three-high and old four-high designs did in fact reduce the unit pressures in the neck bearings, and so did raise the possible rolling speeds that might have been attained, but no notable use was made of this fact because there was no reason for raising the rolling speed in dealing with the relatively short pieces (plates and sheets) that were rolled on the early three-high and four-high mills. One exception to this statement should be noted, this being a disclosure by Mr. Tytus in 1925 as to a proposal to utilize three-high mills to raise rolling speeds somewhat in a hot sheet mill, so as to help obviate the necessity for re-heating in a continuous hot sheet process. It should be said here that a three-high or four-high mill which carries the rolling load on brasses can roll short pieces at speeds which cannot be maintained in rolling long pieces, long enough to be classed as strip. This is because lubrication of brasses can be re-established, and heat of bearings dissipated, when the load is off of the mill between pieces, but such lubrication and dissipation of bearing heat cannot be sufficiently effective for the rolling of more than a certain limited length of piece.

Whatever the facts may be as to the origin of the four-high roller bearing mills, it is agreed that it was the urge of the development of the strip process, and not of the sheet process, that stimulated this recent development.

To focus attention on the one essential of the new strip processes in general, it should be said once for all that the essential feature is the four-high roller bearing mill stand, and that there are two essential features of this essential mechanism. The first feature is the fifty-year old idea of stiffening a mill against distortion by the rolling load. The second

feature is the ability of the mill to perform perfectly at high speed, without any distress from bearing troubles, in rolling the very longest pieces that may be involved.

High speed has, of course, always been an essential in rolling hot strip, so that the four-high mills have not had to raise the speeds employed in hot rolling, but they have vastly increased the possible widths of strip that could be rolled. In the field of cold rolling, the four-high roller bearing mills have not only vastly increased the possible rolling speeds, but have at the same time also greatly increased the possible widths of any given gauge over former practice. Wide thin cold strip could have been produced by four-high mills employing brasses to carry the rolling load, but only by resorting to very low speed. Very little was in fact done on this possible stage of progress before the roller bearing mill, with its higher possible speed, came in to occupy that whole field.

The one physical fact on which these notable advances rest is the ability of a roller bearing, if sufficiently large, to carry very heavy loads at high speeds without troublesome heating or serious wear and upkeep. These bearings themselves could not be applied in heavily loaded two-high mills on account of inherent space limitations. Two-high mills which are not heavily loaded, such as bar mills and hot strip mills rolling the narrowest products, can be fitted with roller bearings with beneficial, though not revolutionary, results. Such mills carry light loads on the neck bearings relative to the loads carried in strip mills, which, by definition and practice, mean mills capable of rolling that material of a width approximating the available space between housings. The space limitations which precluded using roller bearings on two-high strip mills did not apply to properly proportioned four-high mills, and, as soon as this fact was recognized and applied in practice, there was naturally a revolutionary advance in the whole related art.

It is apparent at a glance in comparing the four-high roller bearing stand with the equivalent two-high stand, that the former is very much more expensive. In spite of this fact, and other things being equal, it is still not seriously argued that the four-high stand is not well worth the difference in cost where its use is justified. However, there still remains a wide-spread misconception unfavorable to the four-high mills on the ground of high first cost. This idea dates back to the first wide-spread use of these mills in which they appeared in continuous trains.

It seems well right here to criticize two features unfavorable to continuous mills in general, both these features assuming greater importance as the mills are widened out.

The first feature has to do with the inherent inability of the mill stands to yield a service commensurate with their cost on account of the relatively low speed imposed upon them. This is true in greater or less degree of every stand except the last or delivery stand, which runs at the highest speed. The criticism applies most sharply, of course, to the first stand, which is moving at a very small fraction of the speed of which it would be capable if operated independently of the following stands. It results then, especially in the case of wide continuous hot mills, in multiplying by four, five, six or more the first cost that is necessary to obtain the benefits of four-high operation. This consideration of the inactivity of expensive four-high stands in a continuous mill led me some years ago to contrive to use one single four high reversing stand to do the entire work of the continuous mill; this seeming to be a reasonable undertaking from the fact that the continuous stands were really duplicates of each other, differing only in that the screwdowns of the successive stands were farther advanced with the progress of the piece. The success of such a development would naturally mean a tremendous saving in first cost, and the full speed activity of the one single stand would seem to promise to yield in output a very fair fraction of the capacity of the continuous mill. After experimental development, which took about two years, such a mill was developed to a successful issue somewhat over a year ago. For lack of time, it is not intended to dwell too long this evening on detail discussion of this single stand hot mill, but it seems proper to say that the capacity of such a mill can be stated from experimental data as in excess of ten tons per hour per foot of width. This figure applies to steel rolled to 12 gauge from an initial slab thickness of four to five inches. The weight of single piece practical to roll in this type of mill is easily as great as one ton per foot of width, which is in excess of the weight possible to produce in the existing continuous hot mills.

The ability of a hot mill to produce strip in extraordinarily long lengths has been made important principally by a special requirement of the single stand reversing cold mill. This requirement will be explained later in discussing the cold mill.

The ability of the hot mill to roll pieces of extraordinary length is due to provision for maintaining any desired rolling temperature by keeping the hot strip on coilers in hot chambers close up to the mill on either side. Maintaining in this way any desired temperature throughout the rolling operation not only facilitates the rolling itself, but takes care of special metallurgical requirements of a number of metals such as high silicon steel, monel metal, high carbon steel, brass and extremely low carbon metals of the character of Armco iron.

In addition to holding desired rolling temperatures in the strip, a fortunate result of storage in the hot chambers during the rolling is a pronounced tendency to keep the edges of the material notably hotter than the interior, this being exactly the opposite of the condition in all other hot rolling practice, where radiation is taking place, which naturally results in leaving the edges colder than the interior. It has been found that the maintenance of a high temperature on the edges of the strip in this new type of mill contributes very favorably to preventing the wear of the rolls at the point where the rolls ordinarily cut out first, that is to say, at the part of the rolls that is rolling the edges of the material.

Criticism of this single stand mill has centered principally on the fear that work rolls that are performing the whole rolling operation from slab to finished product would wear out so fast as to make the whole mill impractical. In answer to this criticism it can be said that sufficient work has already

been done on this type of mill to enable us to say that on low carbon steel a pair of rolls will produce a material of good finish after producing sixty (60) tons per foot of width of product of 12 gauge. This would mean in the worst case changing rolls once every six hours when working at normal capacity. This is a conservative statement as to rolls of indifferent quality that have so far been used, and improvement in this respect can be looked for whenever better rolls become available.

It is admitted that rolls must be changed in this mill at shorter intervals than is necessary in a continuous mill. Over against this disadvantage, however, it can be said that when attention is once focused on providing a roll-changing rig capable of changing rolls in a few minutes, which is clearly in sight as a possibility, this objection to the mill on the ground of rapid roll wear very largely fades out. When wide widths of product are to be considered, the only alternative to this mill and a good roll-changing rig is the initial expenditure of extra millions of dollars for a wide continuous mill. The argument then seems to stand in favor of the single stand mill by a very wide margin.

There has been much criticism of this hot mill from some fancied inability to get rid of scale. This criticism can be based upon nothing but the fact that the one only existing mill of this type happens to have none of the ordinary provisions for taking care of initial furnace scale. However, there is no reason for not installing any of the well-known scale devices in connection with these mills, just as they are installed in connection with continuous mills. In fact the advantage seems to lie rather in favor of the single stand mill from the fact that it provides for sharp bending of the material at each pass throughout the coiling operation, thus loosening and throwing off the secondary scale continuously, this feature not appearing at all in continuous mills.

There is no known limitation on this mill, in comparison with continuous mills either as to width or as to the finest gauges possible to roll, the advantage, if any, seeming to be in favor of the single stand mill on account of easy maintenance of desired rolling temperature.

Much of the foregoing criticism of continuous mills applies as well to continuous cold mills, and this consideration had much to do with my preference as early as ten years ago, for developing the four-high cold stand for single reversing operation, aiming at getting high capacity by extraordinarily high speed and correspondingly high power in one stand, rather than to encounter the first cost and prospective operating difficulties of continuous cold stands.

The second general criticism of continuous mills has to do with a consideration just now mentioned, which is the operating difficulty of continuous mills when they attempt to roll difficult sections, by which is meant sections that are wide relative to their thickness. It has long been known that such sections require close following up by adjustment of screwdown, etc. even when rolling in single stands. It was the prospective difficulty of making and maintaining proper simultaneous adjustments in continuous stands that led me to avoid an attempt to employ them on difficult thin sections. From experience of all parties up to date, it seems about time to agree that even outside of the relatively high cost of continuous cold mills, they should be regarded as suitable only for rolling products that are relatively crude and easy to roll. Conversely the single stand cold mill, just as in old two-high practice, should by this time be regarded as able to roll successfully the thin, wide sections much better than the continuous mill.

Since the first mention of general criticisms of the continuous mill, I have been stating general reasons for confining my own developments, both in cold and hot rolling, to the operation of single stands, rather than continuous stands. From here on I will discuss only the single stand cold mill, to which perhaps I have been expected to confine my talk entirely.

The aim in the single stand cold mill development was to realize in the very highest degree the full capabilities of the four-high cold mill by exaggerating all of its inherent merits. The practical aim was to produce tin plate by cold rolling by a cold strip process, cheaper and better than by hot pack rolling, and without arduous labor.

First, to take care of the rolling pressure without distress in bearings at high speed, use was made of very small work rolls to give very small working pressure. With this small work roll diameter was combined an exaggerated backing roll diameter, which should give both unlimited stiffness to the mill and accommodation for roller bearings so large as to run a lifetime at high speed without deterioration. By high speed is meant rolling speeds ranging from a figure above the speeds formerly employed up to speeds of the order of 1500' per minute or more. It was apparent that a limitation on smallness of work roll was imposed by inability of a roll of less than a certain diameter to transmit the necessary driving torque. Since, however, more or less delivery tension is always necessary in cold rolling to yield straight unwrinkled product, a happy solution of the small roll difficulty appeared in letting the delivery tension furnish all the motive power, thus relieving the work roll of torque transmission entirely. This solution of the torque difficulty has enabled us to use work rolls as small as 2" diameter 7" long, 3" diameter 20" long, 5" diameter 38" long; the length mentioned being the length of body between neck bearings. The 2" and 3" diameter rolls are small enough to obviate intermediate annealing in rolling the hardest metals, practically from any gauge down to any other desired gauge, without an intermediate anneal. This cannot be said of the 5" diameter rolls, which, however, enable the rolling of low carbon steel to any desired degree of reduction as in tin plate production, without intermediate annealing.

By way of illustration of the capabilities of these cold mills resulting from the smallness of the rolls they are able to use, it can be said that the very tough stainless alloy, 18% chromium, 8% nickel, has been rolled between 3" rolls from an initial thickness of 1/4" and width of 18" down to .01" thick without an intermediate anneal. With the 5" diameter rolls we have rolled low carbon steel 38" wide from an initial thickness of .080 down to final thickness of .003 without an intermediate anneal. In cold rolling tin plate an initial thickness greater than .080 is not at all objectionable, in fact an initial thick-

pass as great as 33% maximum may, in certain cases, be advantageous.

These performances as to avoiding intermediate anneal, when taken in connection with the widths that have been mentioned, make out a very strong case for the use of small diameter work rolls. When the great length of these rolls relative to their diameter is considered, it will be seen to have been demonstrated that work rolls of these extreme lengths are stiff enough of themselves to obviate the necessity for lateral support such as is provided by so called "cluster" mills. The controlling reason advanced for the cluster design is that it provides a needed lateral support for relatively small work rolls. In answer to this fancied advantage of cluster mills, it should be said here that the four-high design carried to the extremes that have been indicated above, proves of itself that there never is any real occasion to support work rolls in the cluster manner. By this is meant that for any assumed diameter of work roll, and any desired corresponding width of mill, there is always a stiffer mill available of the four-high design than is possible in the cluster design. Stiffness as mentioned above means stiffness in the vertical direction.

As to stiffness in the horizontal direction, and any fancied need for such stiffness, it can be said that no existing four-high mill has ever suffered for lack of horizontal stiffness, even when employing the extreme proportioning of work roll dimensions that we have just been mentioning. We are, in fact, prepared to go much farther in increasing the ratio of mill width to work roll diameter by abandoning, in extreme cases, the neck bearings on work rolls and substituting a babbitted bearing which engages the whole work roll body. Experiments have clearly indicated that this is feasible. When this is done, work rolls small enough to roll the hardest materials without intermediate anneal can be employed on mills of practically unlimited width.

Somehow there seems to be an impression to the effect that this type of cold mill is inherently unable to take heavy drafts, also an impression that the high speed at which it is operated is a controlling factor in rendering it unable to take heavy drafts. This erroneous impression is readily traced back to the fact that some of the earliest mills of this design happened to be used entirely on special materials of extremely light gauges of only a few thousandths of an inch. When, however, the mills were put to work on much heavier products, such as tin plate, motors and gearing were provided for standard reductions of 18% on every pass, and it is an everyday practice on some of these mills to take reductions as high as 30%, aiming always as far as possible to use up the full overload capacity of the motor, in the form of torque or in the form of speed, or of both combined. In answer to all doubts as to limited capacity for drafts, it should be said that these mills are now being put out equipped to employ more horsepower per inch of width of mill than any other cold mills in existence.

We are hearing reportings of some startling performances of cold mills in taking reductions of 50% per pass and the like, but reports of these spectacular performances are not accompanied by equally glowing accounts of the accuracy and uniformity of the gauges of the product so produced, nor of the flatness and generally workmanlike appearance of the product. Viewed historically, it should be remembered that in the old days of necessarily slow speed cold rolling, the only way to increase production was by taking heavier and heavier drafts, up to the point of failure of the mill to make the reduction. However, now since unlimited speed is available, it is no longer to be regarded as a valuable achievement to make spectacular drafts, if in making such drafts any one single adverse effect results, such as failure in accuracy or uniformity of gauge, buckled or wrinkled product, and the like. While on the subject of accuracy of gauge, it should be said first that a mill employing very small rolls and excessively stiff backing rolls is inherently a mill for producing very uniformly gauged material.

Conversely, the worst form of mill to yield uniformly gauged product, especially in thin gauged product, is a mill employing large work rolls. It happens that the spectacular performances just referred to of 50% cold reductions per pass have been on mills employing work rolls of over three times the diameter that we find most suitable. In the light of simple calculation born out by experience, we feel justified in considering heavy drafts and large work rolls to be a vicious combination requiring a maximum first cost of apparatus and yielding in return the poorest practical result. In addition to tremendous first cost of mill structure and bearings to carry the rolling load of unnecessarily large work rolls, the load on bearings runs so high, if heavy drafts are taken on thin material, as to insure the rapid deterioration or destruction of these expensive bearings.

The main disturbing factor in obtaining uniform gauge is the inevitable change of temperature in the mill parts. Up to about two years ago this disturbing factor of varying temperature, with resulting contraction and expansion of the mill parts, necessitated frequent stops to apply the micrometer to the material as a guide in making necessary adjustments. If such stops were not sufficiently frequent, mill temperatures often in the meantime would get out of hand to the point of producing serious gauge variation, or even of breaking the material from excessive drafts, this latter trouble being encountered especially when the gauges were relatively light.

We were hence confronted with the problem of devising means for reading accurately the gauge of the rapidly moving strip, and we aimed at readings accurate to .0001". This degree of accuracy is commonly considered unattainable with the ordinary micrometer, even without the difficulties added by measuring an object that is in rapid motion. The devices that failed are not of interest here, but the device that succeeded deserves description fully, as much because of its rugged simplicity as because of its successful performance.

The principle employed in this device is the old principle employed in sheet mills, of measuring an initial thickness and length, and thereafter observing only the increasing length to determine the decreasing thickness. To have used the bare principle, as in sheet practice, would have told only the average thickness of a long piece, leaving intolerable errors above and below such average still unknown and uncorrected. To surmount this difficulty we contrived not to compare long lengths but to compare

very short lengths, and to make such comparisons continuously by employing a simple differential device.

This device simply indicates errors in any desired relative velocity of the strip entering and leaving the mill, a geared planetary member moving backward or forward to show any error in the desired length of material on the delivery side of mill. Assume that the desired gauge is .010" and that an error of .001" is to be observed. This is an error of one per cent and will hence cause an error of .1" in a length of 10 inches or an error of 1/4" in 25 inches. This latter length is all that need be rolled to produce one quarter inch of motion of the indicator which the operator is observing, and he immediately makes a slight screwdown adjustment to bring the indicator to rest again. The operator works the screwdown adjustment so as to keep the planetary indicator from moving either forward or backward, thus insuring that there will be as little error in desired length as a fraction of an inch in a mile of product. It will be seen that this negligible error in length applies not only to the total length but to all small component parts of the total length. Hence the overall result is to yield a final product that bears any desired ratio of thickness to the thickness of the original raw material. The only micrometer measurement is measurement of thickness of the raw material. It will be seen that errors in measuring the thickness of the raw material affect the final thickness only fractionally. Thus an error as great as .001" in measuring raw material .100 thick produces an error of only .0005" in final product .010" thick.

The overall result of the use of this device, as to gauge accuracy of product, is to enable the production of material at the full speed of the mill and without stopping, with such accuracy as to make any seeming inaccuracy in the product cast as much doubt upon the micrometer as upon the gauge of the material. The other equally important benefit from the use of this device is a vast increase in the capacity of the mill, amounting in the case of fine gauge product to an increase of about 100% in all day capacity.

Once having attained full speed operation of the mill without interruption for applying the micrometer, the cost per ton of cold rolling steel strip for tin plate from .030 to .010" has come down to as low a figure as $3.50 per ton, this cost including direct labor, power, entire roll cost as to first cost and all re-grinding, water, oil, maintaining guides, and all repairs. Upkeep of main bearings over several years of such operation, so far experienced, has been zero.

The preferable initial thickness of pickled hot rolled strip entering the mill for tin plate production is about one tenth inch, and the preferable length of such raw material is in the neighborhood of five to six hundred feet or more.

This mill, from its ability to cold roll readily and cheaply from heavy gauge raw material to fine gauge product, yields two results, both as valuable as they have been unexpected in the cold rolling art. First, the ability to start the cold rolling operation with relatively thick material yields a saving in pickling and hot rolling that is not offset by the trifling extra cost of the first pass or two of the cold rolling operation. Second, the unusual amount of cold reduction that is made economically possible without interposing an anneal, yields a superior metallurgical result after a final heat treatment, this being found to be notably true in the case of full finished sheets, and any other products wanting the best deep drawing properties.

The special requirement of extraordinary lengths of raw material is a peculiarity of this mill, mainly for two reasons: The primary reason is that the high speeds attained on the mill would not be practical, in view of the reversing operation, if high speed were of only momentary or short duration, as is necessary with short pieces. Once having long pieces available, the high speeds can be maintained for long runs between reversals, thus cutting down the idle time of reversals to a tolerable fraction of the total time. Another way to regard the advantage of long pieces is to consider that the operator does precisely as much work on a short piece as on a long piece, his work consisting in slowing down, stopping, screwing down, and starting back again at every reversal. Thus the operator's labor and the lost time are both precisely the same on a small piece as on a larger one, making costs and capacities thus largely dependent on working with sufficiently long pieces.

A secondary reason for preferring long pieces is that the ends of the raw material that are permanently attached to the drums have a certain minimum of waste length which forms an objectionable percentage of the total length when the pieces are short, but a negligible percentage when the raw material is in long pieces such as mentioned above.

While dwelling on this requirement of the cold mill for exceptionally long pieces of raw material, it should be said that this prospective demand for long pieces was one of the reasons for the development of the single stand hot mill, which is inherently able to produce extraordinarily long lengths without difficulty.

The capacity of this cold mill in producing base gauge tin plate strip of .011 is easily one ton per hour per foot of width. Power consumption is about two kilowatt hours per ton of such product if the bare, useful mill requirement only is considered, and about 120 kilowatt hours per ton if power consumption of motor generator sets during idle periods and power consumption of all plant auxiliaries of all sorts is included.

Still another erroneous impression concerning this mill should be corrected. This has to do with the mistaken impression that the mill has economic advantage only in rolling relatively very thin products, where avoidance of intermediate anneals is a great factor. It is true that the mill has become best known for its startling economies in the field of light gauge products. However, its capabilities as to high speed, and accuracy and flatness of product give it an economical field in products as heavy as full finished sheets. To realize these advantages on such heavy products it is admitted that very long pieces of raw material are necessary, but it is expected that our novel hot mill shall produce these necessary long lengths.

A closing remark should be made concerning the electric drive that is used on the single stand hot mill and the electric drive that has been found best for the reversing cold mill. In both cases, the Ward Leonard system for the control of a direct current

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motor has outstanding advantage over all alternatives. Mr. Mohler, who will follow me, happens to have had intimate personal experience in both these classes of drive, and I am very glad to have him present to discuss these matters in the light of his experience.

Electrical Equipment for Steckel Mills

By F. MOHLER
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Presented before Cleveland District Section of the A. I. & S. E. E., December, 1932.

After listening to such an able and interesting presentation of this rolling process, by Mr. Steckel, and his description of the precision mills which have made this process possible, I present the following discussion of the electrical equipment with somewhat of a feeling of humility. However, it is indeed a rare privilege to be given the opportunity of discussing the electrical details on the same program in which the mechanical details are presented by the mill builder himself.

The primary object of any rolling mill is to produce steel, but steel for a definite purpose, having definite physical properties. The machine must not only produce the desired product, but must have an output which (even under the present state of competition) will pay a reasonable return on the capital invested. Although these are questions primarily of mill design, the electrical equipment must be fashioned with them in mind.

We have here a mill for producing exceedingly thin strip of very high quality, gauge accuracy, and finish. As Mr. Steckel has explained to you, one of the fundamentals is that of pulling the strip through the rolls. The working rolls are not driven—all power for rolling is applied through the strip itself. Bearing in mind the product, it is obvious that torque must be applied very gradually to the motor which drives the reel during starting and accelerating; otherwise, the strip may be stretched unduly, or even broken, with resultant variations in gauge and possible damage to the rolls.

This fact gives us a clue to the answer of one of the questions in our minds which occurs most frequently. Is a separate generator necessary?

It is commonly granted that the adjustable potential system of motor control, wherein the motor is connected to a separate generator and accelerated

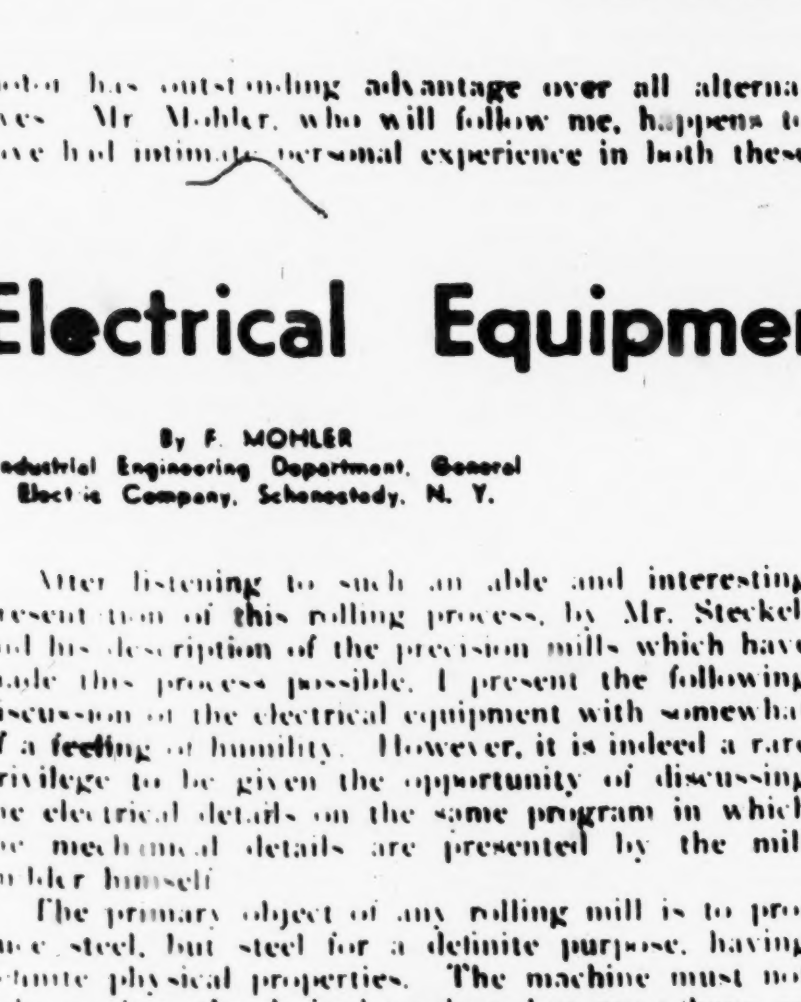


FIG. 1.

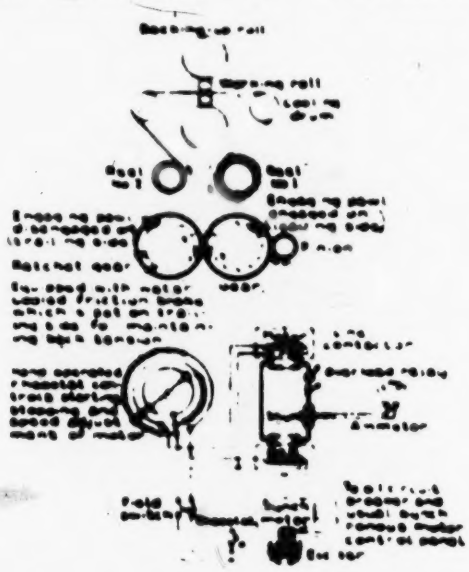


FIG. 2.

by gradually increasing the applied voltage through control of the generator field is the smoothest known method of accelerating. It would require a great number of accelerating points to obtain comparable acceleration with rheostatic starting, whereby the motor is connected to a constant potential source of power through a resistor which is then short circuited in definite steps. Furthermore, because of the length of time required for satisfactory acceleration and the number of reversals necessary, the resistor losses would become quite appreciable.

Other important factors are those of flexibility of control and ease of manipulation. These two factors are conducive to high and economical production. For instance, it is desirable to arrange the equipment so that acceleration may be stopped at any speed for gauging or inspection. Furthermore, if a flaw appears in the strip, the equipment must be stopped very quickly to prevent possible damage to the rolls. In addition, a good operator can tell a great deal about the strip he is rolling by its appear

ance, vibration, etc. From this he determines the rate of acceleration and maximum speed at which he can roll. He learns "the feel" in some mysterious manner and rolls accordingly. In order that he may give his undivided attention to the strip, the operation has been simplified and, as you shall see later on, all control is centered in a single handwheel.

The adjustable-potential system of control lends itself so readily to the foregoing requirements that the additional expense of the separate motor-generator set is considered warranted.

With this as a background, let us consider the actual equipment that is being used for these mills at the present time.

Fig. 1: Here is a small mill driven by a 100 H.P. motor.

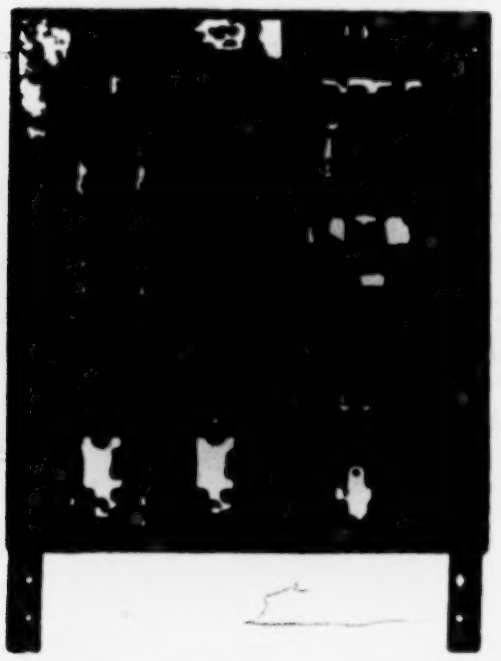


FIG. 1.

The electrical equipment consist of: an adjustable speed d-c. motor; a motor-generator set with direct connected exciter for supplying d-c. power; a control panel; a hand operated combination rheostat for the control of starting, stopping, and speed adjustment of the drive; an ammeter; an exciter field rheostat; and starting equipment for the synchronous motor driving the motor-generator set.

Fig. 2: Before going into the details of the control let us review briefly the gearing and method of driving. It will be noted that the main gears rotate in opposite directions. Therefore, it is not necessary to reverse the direction of rotation of the driving motor but merely to engage one pawl or the other. This is done by a lever which is near the center of the mill.

From the simplified diagram it can be seen that the control of motor speed is obtained through the manipulation of the hand operated rheostat. When it is moved from the "off" position, the line contactor closes, connecting the motor to the generator. Continued turning of the handwheel first strengthens the field of the generator until full voltage is obtained, and then weakens the field of the motor until the desired rolling speed is reached. If the handwheel is turned in the other direction, the motor field is gradually strengthened, then the generator field is weakened, and finally the line contactor is opened. A severe overload will cause the line contactor to open. However, the control is so arranged that the rheostat must be returned to the "off" position before it can be closed again. Furthermore a cemf relay prevents reclosing if there is appreciable voltage across either motor or generator.

The control for the synchronous motor has been omitted because any recognized type of control is satisfactory.

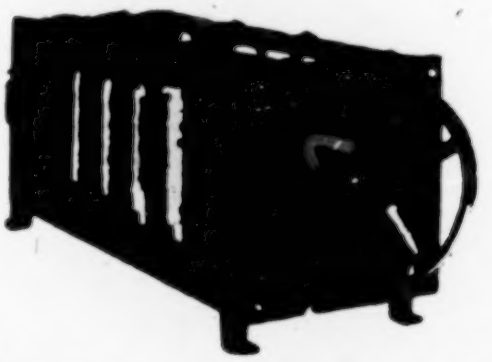


FIG. 4.

Fig. 3: The control devices which you have just noted from the diagram are mounted on a very compact panel. Here is the line contactor, the overload relay, the control relay, the cemf relay and the field and control switch.

Fig. 4: Particular attention has been given to the design of the combination rheostat. The construction is very rugged so as to withstand the severe mechanical and electrical wear imposed by practically continuous operation. Ball bearings and means for lubrication are provided and are arranged in such a manner that the rheostat operates very easily. A large number of points are used in both the generator and motor field sections in order to give small increment changes in speed.

Fig. 5: The rheostat as well as the control panel is placed back of the mill on a common steel structure. The rheostat is connected to the handwheel by a shaft extension. The handwheel is located so the operator can reach it with either hand while observing the strip on either side of the working rolls. On the larger mills where the housing is very wide a handwheel may be placed at either side.

A large ammeter with illuminated dial is placed

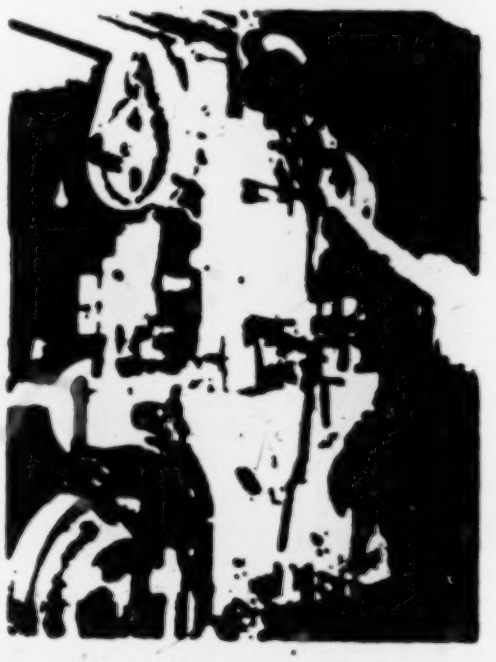


FIG. 5.

on the mill housing for the convenience of the operator in determining the load on the motor, and thereby the approximate tension in the strip.

As the mills increase in size, it becomes necessary to place the driving pinion between the gears

connected to the reels. It follows that the reel gears will operate in the same direction, and it becomes necessary to reverse the direction of motor rotation in order to reverse the direction of rolling. This is accomplished by using reversing contactors for the generator field. These contactors are controlled by a track type limit switch which is operated from the lever which controls the engaging pawls.

Another feature which is desirable on the larger mills, because of the greater stored energy in the drives, is that of dynamic braking. Under any emergency condition, such as a severe overload, which causes the line contactor to open, dynamic braking is applied so that the mill will stop quickly.

Fig. 6: Here is a panel mounting the control devices for these larger reversing mills. You will note that it is practically the same as that for the

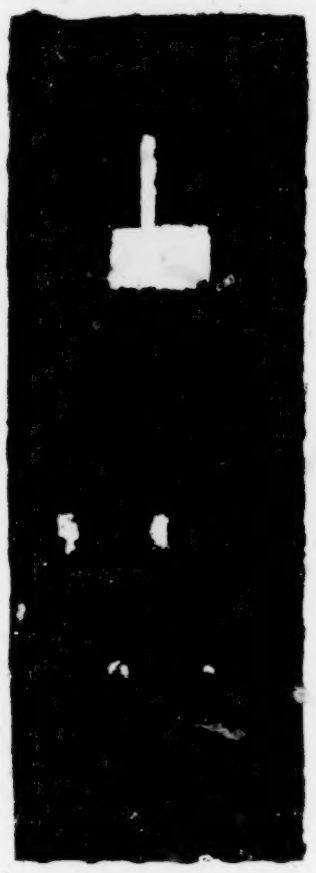
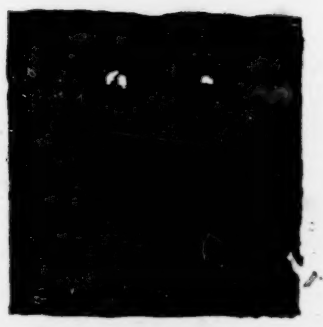


FIG. 6



small mills except for the addition of the reversing contactors and the dynamic braking contactor.

One requirement of this mill, as pointed out by Mr. Steckel, is the use of back tension on the strip.

In general, the power required for hold-back tension is approximately 10% of that required for rolling.

There are two methods of obtaining this hold-back tension—by using friction brakes and by using electric regenerative braking.

The choice, of course, is a question of economy. On the smaller drives the initial cost of the necessary electrical equipment, mechanical arrangement, gearing, etc., greatly outweighs the saving in power obtained. On very large drives, however, the use of regenerative braking may cause an appreciable saving.

In case regenerative braking may prove economical, the following scheme has been proposed. A small drag generator of just sufficient capacity to maintain the desired back tension will be geared to each of the reels. These will be alternately (depending upon the direction of rolling) connected to a booster motor forming a part of the main M-G. set. The output of each generator will be controlled by a constant current regulator so that constant tension is maintained.

After all is said and done, however, simplicity is the watchword for these drives, and it is reasonable to assume, therefore, that the very excellent traction brakes, which the Cold Metal Process Company has developed for the purpose of maintaining back tension, will be used on most of the future drives.

And now a word about the motor—its rating, features, etc.:

I might say at the outset that Mr. Steckel and others of his organization have done considerable in determining from actual tests, the strip pull required for various drafts on the materials rolled in his mills.

Allowable strip pulls, strip speeds, draft and the tonnage to be obtained are so closely related to the mill design that it is quite necessary for the mill builder to either calculate the actual motor required or designate the schedule and strip pulls so that the electrical manufacturer can calculate the root mean square values.

As a matter of fact tentative motor sizes varying from 50 H.P. to 1750 H.P. have already been selected for the various mills and tonnages, but subject to change depending upon the various combinations of the above factors which may be encountered on a particular application.

It has been found that for various schedules the most economical motor which can be used should be capable of taking 150% load during the early passes. Since the early passes are usually taken at full field speed and since these passes are of rather short duration, a mill motor which will meet the NEMA standards is usually satisfactory.

The motors are shunt wound - first, because there is no particular merit in building them compound wound, and second because the necessity of reversing the compound field is somewhat of a nuisance.

So far, there has been no need of forced ventilation, but in view of possible conditions which may arise in connection with oil or acid fumes and the like, it is recommended that the motors be built so that enclosing covers may be added if necessary.

Frequently the question is raised as to WR². I should like to remind you, however, that this is not a fast reversing mill. In contrast, acceleration and deceleration are quite slow as compared to a blooming or a slabbing mill. Furthermore, the passes are quite long. It is believed, therefore, that the slight gain which might be made by using a special motor of low WR² is negligible, and unwarranted from a first cost standpoint.

So much for the motor itself.

I should like to mention briefly one point which may have already raised a question in your minds. Since the motor pulls the strip through the working rolls by winding it up on a reel, it is obvious that the load on the motor will increase in direct proportion to the radius of the coil. When the change in coil diameter is quite appreciable, it may become desirable to use a speed regulator so as to maintain a constant strip speed and thereby a more uniform load on the motor. I have mentioned this point to show that it has been considered, and will be used when deemed necessary.

Before passing on to the reversing hot strip mill, let me leave this thought: the outstanding requirements of the electrical equipment for Steckel Mills are smoothness of operation, ease of manipulation, and simplicity.

The reversing hot strip mill is indeed an inter-

esting subject and one, which if covered thoroughly, would take considerable time. Therefore, I am not going to burden you with the details, but will limit my remarks to a few of the fundamentals.

Mr. Steckel has already described this mill, its purpose, and how a slab is rolled down, as quickly as possible so as to conserve heat, to a thickness suitable for coiling in furnaces located on either side of the working rolls.

So far as the slabbing operation is concerned, it is very comparable to our ordinary slabbing mills. However, there is one important difference. The slab is rather long to begin with and attains considerable length before coiling is started. Thus, the passes last for a reasonably long time, and very little can be gained in the way of reducing peak load demands by using the well-known flywheel motor-generator set and liquid slip regulator, or Illgner system. For this reason, coupled with the saving in first cost, it is recommended that a synchronous motor driven motor-generator set be used for supplying d-c. power for these drives.

There is another point which should be mentioned in connection with the main roll drive. It has been the custom to rate reversing mill drives at 50 deg. C. rise, force ventilated. However, due to the long passes and high sustained peaks, which appear to be in the neighborhood of 200% normal load during the early passes, it is quite desirable to base the drives on a 40 deg. C. rise, force ventilated rating.

Fast reversal of this type mill is not essential and has very little bearing on the production capacity because the time of reversal, acceleration and deceleration is short compared to the time actually consumed in rolling. The omission of the special features usually incorporated for obtaining exceedingly fast reversals reduces first cost and simplifies the control.

On the first reeling pass, it is evident that, even though taken at slow speed, the reel on the leaving side of the mill must be accurately synchronized with the delivery speed of the strip—if it is running too fast the end of the strip may pull out of the blades on the reel or if it is running too slow the strip may cobble between the mill and reel.

It might be mentioned that the pinch rolls are raised on the leaving side because they are only required for entering the piece into the main rolls.

After the reeling operation is started, the mill is accelerated to the maximum allowable speed for that pass. During acceleration the reel must be forced to stay in step with the mill motor. In addition, as the rolling progresses, the diameter of the coil increases and it must be slowed down accordingly. The rate at which the reel motor must slow down depends upon two factors—delivery speed, and the thickness of the strip.

As the end of the piece approaches the mill during the first reeling pass, the mill is decelerated to a slow speed.

The pinch roll on the leaving side is then lowered and it too must be in step with the mill. Just as the end of the piece passes through the mill, but before it passes through the pinch rolls, the mill must be stopped. The mill is then reversed and the pinch roll feeds the strip into the mill. Threading the other reel, etc., is the same process as that just described. In connection with the reel which is now unwinding, it should be noted that its speed must now increase as the coil unwinds. Furthermore, a new problem has entered the picture. The speed of the reel depends on the entering strip speed which no longer corresponds to the mill motor speed, but is slower by an amount equal to the percentage draft.

Complete control of direction of rotation, acceleration, deceleration, and stopping is centered in a hand operated master switch which may be operated from a point in front of either reel, where the operator can see the threading operation of both the mill and the reel, as well as watch the progress of the winding or rewinding operation, as the case may be.

In order to lighten the duties of the operator and save time, it is proposed to use automatic pre-set screwdown control.

However formidable the electrical requirements may seem, it is a matter of fact that we have obtained very satisfactory operation even with rather meagre and developmental equipment on the experimental mill. With the experience gained on this mill we feel confident of the results to be obtained with the proposed schemes of control which will be used on a new drive.

New Year's Statement

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By A. W. ROBERTSON
Chairman, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

The contrast between January this year and a year ago is marked. A year ago business was running downhill with the brakes off. Now we are no longer going downhill and in some quarters business has improved substantially, although the general standard of business throughout the country is still very low. The future is uncertain and vague in detail but we can see enough to know that 1933 will be a year of gradually improving business. The most hopeful sign is the improved point of view of industrial leaders. The discouraged have passed out of the picture and men of courage and youth are in command.

Everyone realizes that our economic life would be greatly stimulated by some outstanding discovery which would become tremendously popular, making many new jobs and stimulating business generally. I do not think such development imminent nor do I regard it as essential to recovery. The restoration of our factories, commercial buildings, institutions and homes to anything like first class condition after three years of depletion will in itself provide the stimulus we need. Industrial leaders are beginning to recognize this and are planning programs of rehabilitation and modernization on the basis of insuring future earnings. Storekeepers, landlords and home owners are bound to take part in this move-

Opinion of the District Court.

Filed December 28, 1956.

MODARELLI, District Judge.

This action was commenced by The Cold Metal Products Company, an Ohio corporation, against Crucible Steel Company of America, a New Jersey corporation. Plaintiff's claims are that defendant owes it money for royalties pursuant to a patents' license contract dated September 30, 1946.[1] The opinion and decisions of this court relating to several preliminary motions are reported in 126 F. Supp. 546.

The license contract dated September 30, 1946, covered Cold Metal's Reversing Hot Mill Patents. All of the licensed patents related to methods and equipment for rolling metal ingots such as steel, heated to an elevated temperature, into relatively wide and thin gauged strip in lengths sufficiently long to permit coiling the metal on reels during the hot rolling operation. In 1948 and early 1949, Crucible installed a hot strip mill and began commercially to operate it about April 1, 1949. From that date until November 30, 1951, Crucible paid contract royalties amounting to $655,189.54. One of plaintiff's claims is that additional royalties amounting to $161,668.72 are owed for that period. A second claim is that Crucible owes royalties amounting to $329,226.07 for the period from November 30, 1951, to April 1, 1953, during which period Crucible did not pay any royalties.

In addition to the license contract issue, there are patent issues. Cold Metal alleges that although the

1. The contract was terminated, pursuant to its provisions, on April 1, 1953.

license contract has been terminated, Crucible's continued operation of its mill infringes three of Cold Metal's patents.[2] Crucible contests the validity of the three patents.

COLD METAL'S CLAIM FOR ADDITIONAL ROYALTIES FOR THE PERIOD FROM APRIL 1, 1949, TO NOVEMBER 30, 1951.

1. Crucible computed and paid royalties on hot rolled stainless steel which it later cold rolled, by deducting from the base price of hot rolled stainless steel extra charges for annealing and pickling the hot rolled stainless steel.[3] Cold Metal's claim for additional royalties is based on the argument that Crucible should have used the "prevailing regular market price" required under Section III, Paragraph 4 of the contract but that instead Crucible deducted from that price 4½¢ a pound because the material was annealed and pickled before

2. The licensed patents were:

Patentee	Number	Filed	Granted
Steckel	1,857,670	6 15 27	5 10 32
Keeney & Ferm	1,918,968	1 12 28	7 18 33
Steckel	1,977,214	5 4 31	10 16 34
Montgomery	2,072,121	10 21 33	3 2 37
Montgomery	2,072,122	12 4 34	3 2 37
Montgomery	2,087,065	1 19 34	7 13 37
Montgomery	2,116,121	12 21 35	5 3 38
Montgomery	2,214,107	10 23 36	9 10 40
Montgomery	2,219,150	6 7 37	10 22 40

The alleged infringed patents are:

Montgomery 2,072,122, Claims 6, 10, 18, and 19.

Montgomery 2,087,065, Claims 1, 2, 3, 4, and 5.

Montgomery 2,214,107, Claims 4 and 6 "are invalid for lack of patentable invention" (the only patent which has not expired).

3. The parties have stipulated that the amount involved is $100,351.23.

being cold rolled or fabricated.[4] Crucible agrees that the prevailing regular market price controls, but it argues that such price of hot rolled stainless strip, unannealed and unpickled, intended for further reduction by cold rolling, was the base price less the established extras of 4½c a pound for annealing and pickling.

The court concludes that Crucible's deduction was improper. The prevailing regular market price was the "base price" and that price was for the hot rolled stainless strips and coils in the annealed and pickled condition, no extra having been charged to the purchaser for those operations. It is clear from the evidence that it was the practice in the industry to sell hot rolled stainless annealed and pickled strip at the base price without any charge to the purchaser of an extra for annealing and pickling.[5] The reason there was no such charge was that the hot roller manufacturers insisted on performing those operations to permit them to inspect the material before selling it and thereby avoid later rejections by purchasers.

2. The second contract issue is whether Crucible should have included in its computations, scrap resulting in its Agricultural Department from manufacturing disks and plowshares.[6] In addition to Crucible's Hot Rolling Department it has an Agricultural Department where it manufactures agricultural disks and plow-

4. Section III, Paragraph 4 of the contract does exclude from the royalty formula extras charged to the purchaser for annealing and pickling.

5. Even Mr. Glenn, Crucible's vice-president and general manager of sales, who was called as a witness by Cold Metal, testified that no extra for annealing and pickling was charged when stainless steel hot rolled strip was sold to cold rollers.

6. The parties have stipulated that the amount involved is $46,462.93.

shares. Scrap is produced during the operations, and in computing the royalties due on the hot mill operation, Crucible excluded all that operational scrap. Crucible argues that it is required under the contract only to pay royalties on revenue-producing material. Specifically, Crucible points to Section III, Paragraph 5 of the contract, providing that royalty payments shall be made covering "salable production" which is defined as all material "shipped or used."[7]

The court concludes that the operational scrap which Crucible failed to include in its royalty computations was "used" by it within the meaning of Section III, Paragraph 5. The contract does not exclude all scrap from computations under the royalty formula; the only excluded scrap is defective material rejected by a customer or by Crucible and later used by Crucible as scrap or sold at scrap prices. The court agrees with Cold Metal's argument that it is the weight of the material used, i.e., the weight of good material transferred to and used in the Agricultural Department and the selling price of the material transferred there that is the basis for royalties.

3. The third contract issue is whether Crucible should have included in its computations and paid royalties on scrap resulting from slitting in its Cold Rolling Department.[8] In computing royalties, Crucible excluded the scrap resulting from the slitting of material after it had been transferred from the Hot Rolling De-

7. As to material rejected by Crucible and later used by it for scrap, no royalty is payable and Cold Metal does not claim royalties for such material.

8. The parties have stipulated that the amount involved is $14,591.37.

partment to the Cold Rolling Department. Again, Cold Metal argues the deduction was improper because royalties must be computed on the basis of the weight of the material transferred to and "used" in the Cold Rolling Department. And again, the court concludes that Crucible's deduction was improper for all the material was used by Crucible in its Cold Rolling Department.

4. As to the fourth contract claim, the issue is whether scrap resulting from Crucible's inspection of cold-rolled pickled and annealed strip is includible as a royalty base.[9] Here, unlike the other so-called scrap materials, clearly the scrap is rejected by Crucible. Under Section III, Paragraph 5, such material is excluded from royalty computations.

COLD METAL'S CLAIM FOR ROYALTIES FOR THE PERIOD FROM NOVEMBER 30, 1951, TO APRIL 1, 1953.

Cold Metal's second claim is that Crucible owes royalties for the period from November 30, 1951, to April 1, 1953. Cold Metal contends that each of the Montgomery '122, '065, and '107 patents contains one or more claims covering Crucible's hot strip mill and its operation. Crucible, of course, cannot contest the validity of those patents.[10]

The '122 patent relates to improvements in reversing hot mills. The pertinent claims are Nos. 6, 10,

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9. The parties have stipulated that the amount involved is $263.19.

10. See this court's earlier opinion, 126 F. Supp. 546, and *Automatic Radio Manufacturing Co., Inc. v. Hazeltine Research, Inc.*, 339 U.S. 827, 836 (1950); *Hall Laboratories Incorporated v. National Aluminate Corporation*, 224 F. 2d 303, 305-6 (CA 3 1955).

18, and 19.[11] The improvements are directed at the difficulty in causing the material being rolled to enter the rolls properly to prevent cambered strip.[12] Also, there had been difficulty in causing the leading end of the material properly to engage the coilers within the furnaces on opposite sides of the mill and frequently the leading end of the piece was bent, making it difficult to cause the material properly to engage the coiler. The patented solution consists of side guides on both sides of the mill, operation of the guides successively to provide a parallel guiding throat on the entering side of the mill and a tapered guiding throat on the other side of the mill. The patent also provides pinch rolls for feeding the material toward the mill and, after passing

11. "6. In a rolling mill including a pair of housings and work rolls journaled therein, pinch rolls on one side of the mill, and means for raising one of the pinch rolls through a short distance, and independent means for raising the upper pinch rolls through a greater distance.

"10. The combination with a rolling mill having a driving motor and a controller for the motor, of adjustable side guides on both sides of the mill, and means operated by said controller for shifting the guides inwardly on the entrance side of the mill and outwardly on the exit side of the mill.

"18. In a rolling mill, a pair of housings having work rolls journaled therein, pinch rolls on at least one side of the mill for engaging material being worked in the mill, means for retracting one of said pinch rolls when unused for a substantial period, and independent means for temporarily retracting one of said rolls.

"19. The combination with a rolling mill and a roll table for advancing work thereto, of pinch rolls on one side of the mill, one of said pinch rolls being retractible, and means for retracting said roll including fluid pressure-operated cylinders and pistons, one of which has a short stroke for temporarily retracting the roll and the other having a longer stroke for retracting the roll when unused for substantial periods."

12. Cambered strip has a sidewise curvature in the plane of the strip. It is an objectionable condition during the rolling operation.

through the mill, toward the coilers, between passes, whereby the strip is properly started on the coilers. The pinch rolls are automatically raised when the strip has been properly started and they are withdrawn when the material being rolled is handled back and forth through the mill in the flat without coiling between passes. (Exhibit P-3, p. 1, col. 1, line 31 through col. 2, line 6). In the patent it is pointed out that after the strip is started through the mill and into the coilers, the pinch rolls are positioned in the low-lift position on the winding and unwinding sides so that the strip is freed of any pinching action between the mill and the winding and unwinding coilers.

The '065 patent relates to a reversing type of hot mill employing both a roughing mill unit and a finishing mill. All of the claims are pertinent. [13] That patent

13. "1. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body in the roughing mill until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, and, in the same heat, feeding the thinned body to a reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.

"2. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body in the roughing mill until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, trueing the edges in said mill, and, in the same heat, feeding the thinned body to a reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.

"3. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body back and forth in the roughing mill until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, and, in the same heat,

points out that for certain classes of product it is desirable to provide a finish on the hot strip superior to that which can be obtained with a mill in which the entire reduction from the slab to the thin strip is effected by the same pair of rolls. The patentee, Montgomery, proposed taking a slab after it was properly heated and subjecting it to repeated passes through a roughing mill to elongate it and then passing the material, in the same heat, to another reversing mill with heated furnaces on opposite sides and rolling the material while coiling it between passes. Montgomery also proposed trueing the edges in the roughing mill, cropping at least one end between the rolling on the roughing mill and the rolling on the finishing mill, and continuing the rolling on the roughing mill until the breakdown cools to a temperature below that at which free scale forms. According to the patentee the advantages of the patent are

> feeding the thinned body to a reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.
>
> "4. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body in the roughing mill until the body cools to a temperature below that at which free scale forms, and until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, and, in the same heat, feeding the thinned body to a reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill.
>
> "5. In a method of rolling metal strip, the steps consisting in supplying to a roughing mill a heated slab-like body which is too thick for coiling, rolling the body in the roughing mill until it is substantially thin enough to permit of coiling, but maintaining the thinned body in the flat state, and, in the same heat, feeding the thinned body to a reversing mill after cropping at least one end of the thinned body to facilitate its entry into said reversing mill, subjecting it to successive passes therein to reduce it to a desired strip thickness, and coiling it between passes in the reversing mill."

that a higher finish is obtained than by using one mill stand for both breakdown and finishing operations because the heavier scale is eliminated from the material before it reaches the rolls on which the finishing operations are performed; also the output of the finishing mill can be increased because the mill can be operated at higher speeds a greater portion of the time than when the breakdown operations are also carried out on the same mill stand.

The '107 patent is a method patent related to the '122 patent. Claim 6 is the only pertinent claim.[14] One of the principal difficulties with the earlier reversing hot mills was they were incapable of consistently rolling a breakdown without camber or longitudinal curvature, making it necessary to permit the breakdown to coil loosely on the winding reel; there was skidding or axial shifting of the turns on the coil being wound with the result that on the next pass, the back tension imparted to the breakdown by the retarding of the unwinding reel caused an edge to strike the side guides and become folded over into a double thickness. (Exhibit P-5, p. 1, col. 1, lines 12-26).

> "In accordance with the present invention, however, I utilize the pinch-rolls only while starting the leading end of a breakdown through the mill and into the coiling reel on the opposite side, the pinch

14. "6. In a method of rolling strip, the steps including passing a breakdown, heated to plastic condition, back and forth between reducing rolls, uncoiling it on one side and coiling it on the opposite side of the rolls, passing an end of the breakdown entirely through the rolls, frictionally gripping said end to feed it back through the rolls, freeing that portion of the breakdown between the mill and the point of coiling, and tensioning such portion uniformly throughout."

> rolls being thereafter retracted, freeing the strip between the mill and the reel. I then apply sufficient torque to the shaft of the winding reel to tension the portion of the breakdown between the reel and the mill. I also apply a back tension to the portion of the breakdown between the mill and the unwinding reel thereby exerting a retarding torque on the shaft of the latter. By thus tensioning the breakdown, I am able to form a tight coil on the winding reel, thus eliminating 'skidding' and preventing cambering of the product during the later rolling passes." (Exhibit P-5, p. 1, col. 1, line 47, to col. 2, line 7.)

The patentee also points out that the guides on the exit sides of the mill prevent cambering of the leading end of the breakdown until it is engaged by the pinch rolls; the pinch rolls assist in guiding the strip until it is engaged by the coiling reel; the guides will correct any incipient camber before the leading end has entered the pinch rolls and the forward tension on the strip will pull out any camber which the mill tends to produce in the breakdown after it has been started on the reel.

Crucible's mill as constructed and operated on October 16, 1951, when the Steckel '214 patent expired (the Keeney & Ferm Patent having previously expired) embodied two details of design and operation covered by claims in the Montgomery '122 and '107 patents. One of these details was the arrangement of pinch rolls on each side of the finishing stand of the hot mill in such a way that the upper roll of each set of pinch rolls could be raised by the operation of pneumatic cylinders from pinch position to either of two positions of retraction.

known as the low-lift and high-lift positions;[15] the other detail was that the deflector rolls located at the entrance to each of the coiling furnaces were driven by direct connected electric motors.[16]

Crucible contends that by making two changes in the construction of the mill, it eliminated the two details covered by the license, thereby excluding all of the mill's production from the license contract. First, the short stroke cylinders which had previously enabled the upper pinch rolls to be withdrawn from the strip to the low-lift position were eliminated so that the pinch rolls thereafter could occupy only two positions: pinch or fully retracted. An entirely separate roll was added, known as the hold-down or auxiliary roll, one on each side of the mill. These rolls were actuated by wholly separate cylinders arranged so that the hold-down rolls could also be in either an up position 12 inches above the pass line or a down position about 3 inches above the pass line. The hold-down function of the suppiemental rolls, Crucible contends, was neither taught nor hinted at in any of the licensed patents. This change, resulting in eliminating the formerly low-lift, high-lift position of the pinch position, was completed on October 29, 1951. The other change in the Crucible mill involved the installation of magnetic clutches in the drives of the deflector rolls. Provision was made for the rolls to be driven by their motors; this prevented them from being warped by unequal exposure to the furnace heat which would have been the result if the rolls were permitted to stand in one position for a substantial length of time. Crucible argues the only licensed patent claim relating

15. See Claims 6, 18, and 19 of Montgomery '122.
16. See Claims 4 and 6 of Montgomery '107.

to the driving of the deflector rolls was Claim 4 of the '107 patent which included the feature of driving the deflector rolls "to prevent frictional drag on the breakdown" during the coiling-rolling operation. But, Crucible contends, it re-arranged its deflector rolls drive in such a way that during the coiling-rolling operation the deflector rolls were disconnected from the motor drive by the operation of the newly installed magnetic clutches; the rolls were rotated during the coiling-rolling operation solely by such frictional drag as was caused by contact between the material and the surface of the roll. This, according to Crucible, was exactly the way the corresponding deflector rolls had been driven in the expired Steckel '214 patent. The installation of these magnetic clutches was completed on November 19, 1951.

The result of the installation of the magnetic clutch was that each deflector roll was driven when strip was not being rolled, but the drive was interrupted during rolling operations involving coiling so that only the strip served to drive the roll. This change, however, did not affect the operation of the mill. As to the modification of the pinch rolls the result was that the cylinder for attaining the low-lift position was hydraulically operated rather than air actuated. Here, too, however, the change made no operational difference.

Each of the specifications in Claim 6 of the Montgomery '107 patent was followed in Crucible's modified mill. The Crucible mill passes a breakdown, heated to plastic condition, back and forth between reducing rolls, uncoiling it on one side and coiling it on the opposite side of the rolls; an end of the breakdown is passed

entirely through the rolls and frictionally grips the end to feed it back through the rolls; that portion of the breakdown between the mill and the point of coiling is freed; finally, that portion of the strip between the mill and the point of coiling is tensioned uniformly throughout.[17]

In addition to Claim 6 of Montgomery '107, the Crucible mill is covered by Claims 6, 10, 18, and 19 of the Montgomery '122 patent. As to Claim 6, Crucible's auxiliary roll is movable through a short distance to provide the low-lift position; the upper pinch roll is movable by independent means through a greater distance to provide the pinch and high-lift positions. Thus, Crucible having used the substance of that claim, its mill is covered by the claim. *Graver Tank & Mfg. Co., Inc., et al v. Linde Air Products Co.*, 339 U.S. 605, 607, 608 (1950); *Kellett Autogiro Corp., et al v. Brohan*, 24 F. Supp. 81 (D.C. N.J. 1938). As to Claim 10, Crucible's modified mill has a driving motor for the four-high mill and a controller for the mill motor; it also has side guides on both sides of the mill and means operated by the mill motor controller for shifting the guides inwardly on the entrance side of the mill and outwardly on the exit side of the mill. As to Claims 18 and 19, it is clear from Mr. Sachs' testimony[18] that Crucible's mill is covered by those claims.

Crucible's mill also is covered by the five claims of the Montgomery '065 patent. As to Claim 1, "a heated slab-like body which is too thick for coiling" (Transcript, p. 399) is supplied to a roughing mill; where it

17. Mr. Valette, Crucible's expert, so testified.
18. Transcript, pp. 573, 574, 575.

is rolled "until it is substantially thin enough to permit of coiling" (Transcript, pp. 400, 423-425); this is done while "maintaining the thinned body in the flat state" (Transcript, p. 400); "in the same heat" (Transcript, p. 400); the thinned body is fed to a reversing mill where it is subjected to successive passes to reduce it to the desired strip thickness and where it is coiled between passes (Transcript, pp. 400-401, 800-801). Claim 2 differs from Claim 1 only in that Claim 2 includes the step of trueing the edges of the roughing mill —and this too is done in Crucible's modified mill (Transcript, p. 401). Claim 3 differs from Claim 1 only in that Claim 3 specifically includes rolling the body back and forth in the roughing mill, which is also done in Crucible's mill. (Exhibit D-3, pp. 5-6). Claim 4 specifies that the material is rolled in the roughing mill until it cools to a temperature below that at which free scale forms; this also is done in Crucible's mill (Transcript, pp. 802-807, 814). Claim 5 differs from Claim 1 only in that Claim 5 specifies that the material is fed to the reversing mill after cropping at least one end of the thinned body to facilitate its entry into the reversing mill. And this too is part of Crucible's mill (Transcript, pp. 401, 799, 808).

Both parties have stipulated that the royalty amount in dispute for the period from November 30, 1951, to April 1, 1953, is $329,226.07, and the court finds that Crucible owes this amount to Cold Metal. The court also has decided in favor of Cold Metal on the license contract issues involving annealing and pickling ($100,351.23), the blanking of disks and plowshares ($46,462.93), and slitting scrap ($14,591.37). Thus,

the total amount Crucible owes to Cold Metal is $490,631.60 plus interest.[19]

VALIDITY OF PLAINTIFF'S PATENTS

The flash of genius test has been extinguished and Cold Metal has the benefit of a presumption of validity even though this court "* * * is left to the struggle to determine upon which side of a vague boundary line it will place the alleged invention * * *." *R. M. Palmer Company v. Luden's, Inc.*, 236 F. 2d 496, 500 (CA 3 1956). The burden of establishing the invalidity of the patents rests upon Crucible. *Hartford National Bank & Trust Company v. E. F. Drew Co., Inc.*, 237 F. 2d 594, 596 (CA 3, 1956). And commercial success of any disclosures in a patent is evidence of invention. *Palmer v. Luden's, Inc.*, supra; *Hartford National Bank & Trust Company v. E. F. Drew Co., Inc.*, supra.

The Montgomery '065 patent has been held invalid by the Court of Appeals for the Sixth Circuit. *Cold Metal Products Co. v. Newport Steel Corp.*, 226 F. 2d 19 (CA 6 1955). That court held that "In view of the then state of the art, we think that the particular mechanical arrangements disclosed by the patents in suit represented nothing more than a felicitous selection of known elements, none of which contributed in combination any new or unusual function, and that the subject matter as a whole would have been obvious at the time the claimed inventions were made to persons having ordinary skill in the art of hot rolling metals. 35 U.S.C.A. § 103." That decision, of course, is not binding upon this

19. The court's decisions of the license contract issues result in a dismissal of Crucible's counterclaim for overpayments of $9,479.15 and $4,661.00.

court, although it is entitled to great weight. *Standard Brands, Inc. v. National Grain Yeast Corp.*, 101 F. 2d 814 (CA 3 1939), affirmed 308 U.S. 34 (1939).

This court having independently judged the issue of validity, finds the '065 patent invalid. The five claims of the patent all are limited to a method of rolling a heated slab-like body in a roughing mill until it is substantially thin enough to permit coiling, and then in the same heat feeding the thinned body to a reversing finishing hot mill and subjecting it to successive passes to reduce it to the desired thickness while it is being coiled between passes. All of the claims are alike except for details such as trueing the edges of the material in the roughing mill, rolling in the roughing mill until the material cools to a temperature below that at which free scale forms, and end cropping the material before passing to the finishing mill. But the idea of using a roughing mill as a prelude to finish rolling on a reversing coiling hot mill was not new to the art. See Keeney & Ferm '968 and Steckel '214. Even the Cushwa Patent No. 904,605 applied for on August 18, 1905, and issued on November 24, 1908, for a Method of Rolling Sheet Metal disclosed a multi-stand finishing mill.

Claims 6, 10, 18, and 19 of the Montgomery '122 patent are valid. Claims, 6, 18, and 19 relate to a rolling mill with pinch rolls on at least one side of the mill and mechanism for operating them for shifting into one of three positions: pinch, low-lift, and high-lift. The Steckel '214 patent taught only the pinch and high-lift positions. These Montgomery claims added entirely new functions. For example, in the low-lift position the strip is free to enable the coilers and uncoilers to provide uniform tension on the strip. Furthermore, when the

pinch rolls are in the low-lift position they hold the strip inside the side guides, preventing cambering. Additional functions are that damage to the strip is minimized as it strikes the side guides, sidewise movement of the strip is limited, and uniformity of tension is maintained. As to Claim 10, it relates to a controller for a driving motor of the rolling mill with side guides on both sides of the mill, the controller being used for shifting the guides. Crucible contends that this claim is invalid because it is completely anticipated by Steckel '214. But in that patent the side guides are moved by frictional engagement with the table rollers which are driven through shafts and gears by the rolls (the pinch rolls are driven by motors controlled separately from the mill motor). The guides disclosed by Montgomery maintain the strip in the center of the mill and on the entrance side they prevent cambering.

Cold Metal also complains that Claim 6 of the Montgomery '107 patent has been infringed. Crucible not only questions the validity of Claim 6 but also seeks a declaratory judgment that Claim 4 is invalid and not infringed.[20] Claim 6 is invalid. It describes a method of rolling strip by passing a heated breakdown back and forth between reducing rolls, the uncoiling and coiling occurring on opposite sides of the rolls; the end of the breakdown is frictionally gripped and fed back through the rolls and the material is uniformly tensioned.

20 "4. In a method of converting a slab or ingot into strip, the steps including passing a slab back and forth in the flat between reducing rolls to form a breakdown, passing the breakdown back and forth between reducing rolls to form a strip, winding the breakdown on a coiling reel between passes through the rolls, bending the breakdown about a guide roll, and driving said guide roll to prevent frictional drag on the breakdown."

Steckel '670 provides for tensioning hot strip by means of coiling reels, and Keeney & Ferm '214 discloses tension between the mill and the coiler. Since the court finds that there is no substantial difference between Claim 4 and Claim 6, Claim 4 also is invalid.

INFRINGEMENT

There is no issue as to Crucible's infringement of the claims of plaintiff's valid Montgomery '122 patent. Crucible admits that "* * * the construction and operation of defendant's mill * * * were likewise the same during both time periods [the period of the license contract and the period after its termination]."[21] Thus, it is unnecessary for the court again to discuss the construction and operation of Crucible's mill and whether it is an infringement of Cold Metal's valid patent, and the court finds that defendant has infringed upon claims 6, 10, 18, and 19 of the Montgomery '122 patent. The issue of damages shall be referred to a Special Master who will be guided by 35 U.S.C.A. §§ 283, 287,[22] unless the parties can agree by stipulation.

The question of costs and reasonable attorneys fees to the plaintiff will be considered later after hearing counsel on these issues.

The foregoing opinion shall constitute findings of fact and conclusions of law as required by Rule 52.

An order may be submitted in conformity with the opinion herein expressed.

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21. Defendant's Brief after Trial, p. 11.

22. As to the court's power to refer the issue of damages to a Special Master, see *Modern Art Printing Co. v. Skeels*, 123 F. Supp. 426, 434, reversed on other grounds, 223 F. 2d 719 (CA 3 1955).

Judgment of the District Court.

This action, having come on to be heard on the pleadings, proofs, briefs, and arguments submitted by the parties and the Court having rendered an opinion constituting its findings of fact and conclusions of law, it is hereby Ordered, Adjudged, and Decreed as follows:

1. Plaintiff, The Cold Metal Products Company, under the license agreement dated September 30, 1946, shall recover from defendant, Crucible Steel Company of America, royalties for the period from April 1, 1949, through November 19, 1951, in the principal amount of $146,210.38, together with interest upon those royalties at the legal rate of 6% upon each increment of the royalties from the date each increment was due until the date hereof, that interest amounting to the sum of $53,359.89; the total principal and interest amounting to $199,570.27; and the Clerk is directed to enter judgment in favor of the plaintiff and against the defendant for this amount.

2. Plaintiff, The Cold Metal Products Company, under the license agreement dated September 30, 1946, shall recover from defendant, Crucible Steel Company of America, royalties for the period from November 20, 1951, until April 1, 1953, in the principal amount of $334,942.07, together with interest upon those royalties at the legal rate of 6% upon each increment of the royalties from the date each increment was due until the date hereof, that interest amounting to the sum of $88,259.24; the total principal and interest amounting to $423,201.31; and the Clerk is directed to enter judgment in favor of the plaintiff and against the defendant for this amount.

3. Allowance has been made, with plaintiff's consent, in the recovery allowed in the preceding paragraph for an overpayment of royalties amounting to $9,479.15, for which defendant sought recovery in Paragraph 10 of its original answer and counterclaim filed February 16, 1953, as amended, March 23, 1956.

4. Allowances having been made in the recovery allowed in Paragraphs 1 and 2 for the royalties amounting to $5,716.00 accrued from November 20, 1951, to November 30, 1951, for which recovery was sought in Paragraph 11 which was added to defendant's counterclaim by an amendment filed March 23, 1956, that counterclaim is hereby dismissed.

5. Claims 6, 10, 18, and 19 of U. S. Letters Patent No. 2,072,122 are valid.

6. Each of Claims 6, 10, 18, and 19 of U. S. Letters Patent No. 2,072,122 has been infringed by defendant by the use and operation of its hot strip rolling mill from April 1, 1953, to March 2, 1954.

7. Claims 1 through 5, inclusive, of U. S. Letters Patent No. 2,087,065 are invalid.

8. Claims 4 and 6 of U. S. Letters Patent No. 2,214,107 are invalid.

9. Plaintiff shall recover from defendant damages adequate to compensate it for defendant's infringement of Patent No. 2,072,122 from April 1, 1953, to March 2, 1954, which damages shall in no event be less than a reasonable royalty for defendant's use made of the invention of that patent, together with interests and costs as may be fixed by the Court; and this action is hereby referred to DONALD A. ROBINSON, ESQ., as Special

Master, to ascertain, state, and report to the Court an account of and to assess against the defendant such damages as the Master finds plaintiff is entitled to recover from defendant by reason of defendant's infringement of that patent.

10. Plaintiff shall recover from defendant its taxable costs relating to the contractual and infringement issues, excepting the costs of preparation of the drawings, Exhibit P16-1 through P16-23, the costs of which shall not be taxed, and neither party shall recover any costs relating specifically to the validity of the patents in suit. Plaintiff's costs as aforesaid shall be taxed by the Clerk pursuant to the Rules of this Court.

11. Neither party shall be allowed attorney's fees.

12. In respect of any and all relief prayed for in defendant's supplemental counterclaim and in plaintiff's counterclaim not specifically covered herein, those counterclaims are hereby dismissed.

13. This judgment is intended as a final judgment despite the reference of the damage issue to a Master, there being no just reason for delay, and the Clerk is hereby directed to enter judgment in accordance herewith.

s/ ALFRED E. MODARELLI
Alfred E. Modarelli
United States District Court
Judge

Dated: February 8, 1957.

Order Amending Judgment.

Upon the consent of the parties, paragraph 3 of the judgment entered herein on February 13, 1957, is hereby amended by striking out the words "in the preceding paragraph" from line 2 thereof and substituting the words "in paragraph 1."

A. E. MODARELLI
U. S. D. J.

Dated: February 18, 1957

Consented to:

WILLIAM H. WEBB
Attorney for Plaintiff

CHARLES H. WALKER
Attorney for Defendant

Entered: February 18, 1957

Notice of Appeal by Crucible.

Original Filed Feb. 18, 1957.

NOTICE IS HEREBY GIVEN that Crucible Steel Company of America, defendant above named, hereby appeals to the United States Court of Appeals for the Third Circuit from paragraphs 2, 5, 6, 9 and 10 of the final judgment dated and filed February 8, 1957 and entered in this action on February 13, 1957.

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February 18, 1957

Notice of Appeal by Cold Metal.

NOTICE IS HEREBY GIVEN that The Cold Metal Products Company, plaintiff above named, hereby appeals to the United States Court of Appeals for the Third Circuit from Paragraphs 7 and 8 of the final judgment, dated and filed on February 8, 1957 and entered in this action on February 13, 1957.

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